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Typhoon Havens Handbook for the Western Pacific and Indian Oceans Change 4

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Thirty-six ports in the western Pacific and Indian oceans (in the complete publication comprising the original basic volume plus changes 1-4) are evaluated to describe their potentials as havens for ships threatened by typhoons. These evaluations are designed to serve as decision-making aids for force commanders, ship captains, and ship-routing personnel. A general introductory section describes tropical cyclones, and discusses ship performance in storms, warning services, and calculation of danger zones. Mean storm tracks for four ocean areas are depicted in appendices.

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FOREWORD

This publication originally was developed in response to a COMSEVENTHFLT request that certain ports in the western Pacific and Indian oceans be evaluated as potential havens for ships threatened by typhoons.

Incorporating thirty-six port studies in a single reference work, the Handbook is designed to be a decision-making aid for force commanders, ship captains, ship-routing personnel, and others responsible for planning and accomplishing storm evasions in the vicinities of the ports evaluated.

Every effort has been made to make this Handbook as concise as possible, yet sufficiently comprehensive to cover most contingencies that might be encountered under actual or threatened typhoon conditions affecting the ports.

Some of the earlier port studies were undertaken as thesis projects by officer-students in the meteorology curriculum at the Naval Postgraduate School in Monterey, and were condensed for inclusion herein. Subsequent studies were developed expressly for this volume. More recently, in the 1990's, additional ports have been added while some older studies have been updated.

Copies of the first printing were widely distributed to units and facilities afloat and ashore, and are no longer available in the original looseleaf-binder format. Since then, several reprint versions duplicate the material that appeared in the complete first printing. Change 3 provided a revised Section V (Japan) plus some minor format revisions. Change 4 provides four additional port evaluations for Japan (Sec. V), and a revised Sec. VII, Korea, that includes one additional port evaluation.

INTRODUCTION

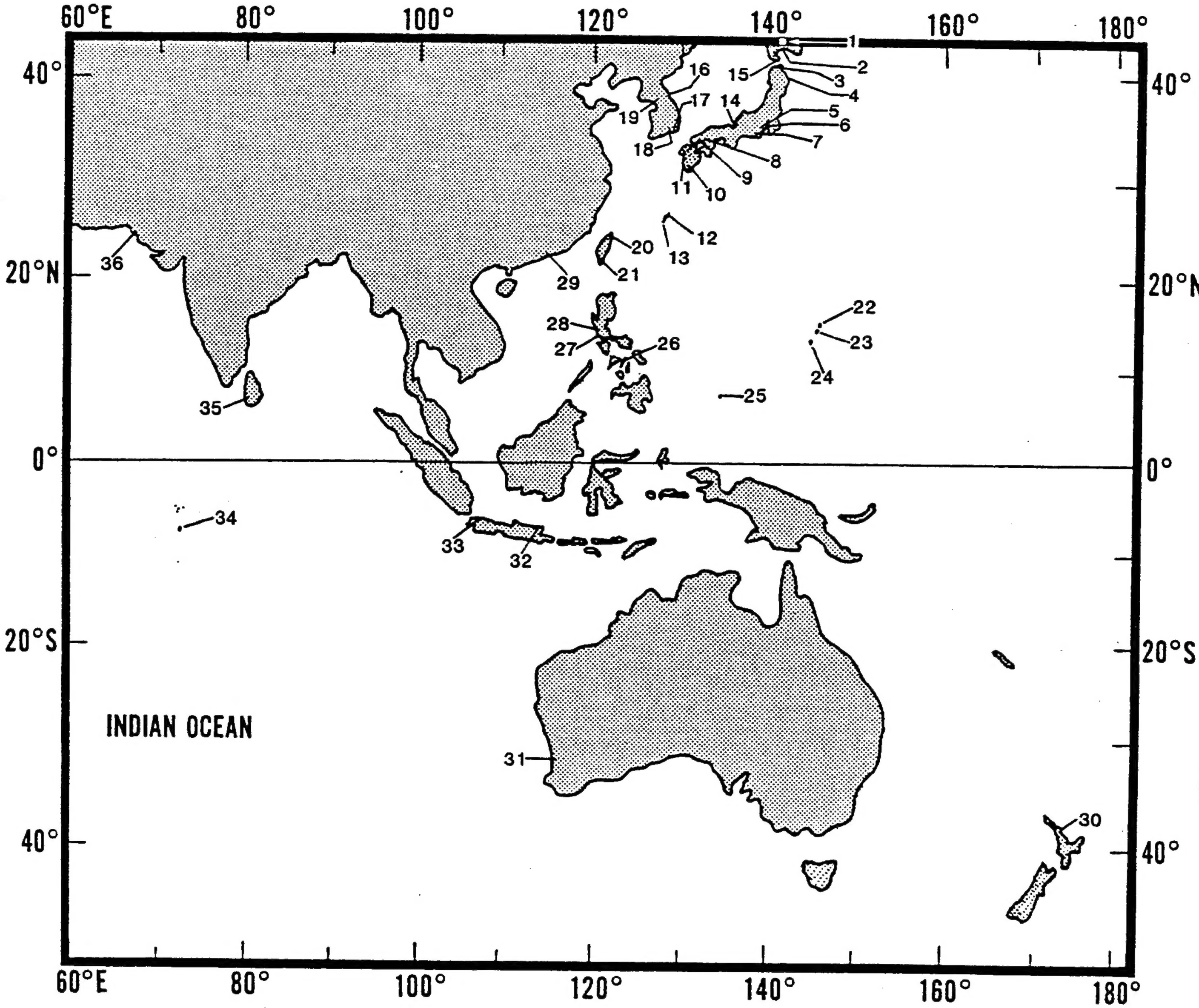
Severe tropical cyclones, also known as typhoons or hurricanes, are among the most destructive weather phenomena a ship may encounter whether the ship be in port or at sea. When faced with an approaching tropical cyclone, a timely decision regarding the necessity and method of evasion must be reached. Basically, the question is: Should the ship remain in port, evade at sea, or if at sea, should it seek the shelter offered by the harbor? This Handbook examines a number of western Pacific and Indian ocean ports and evaluates their potential as typhoon havens. This information should provide useful guidance to commanding officers in answering the above questions.

In general it is an oversimplification to label a harbor as merely good or bad. Consequently, an attempt is made to present enough information about the harbors to aid a commanding officer in reaching a sound decision with respect to the ship. The decision should not be based on the expected weather conditions alone, but also on the ship itself, as well as characteristics of the harbor. These characteristics include natural shelter provided, port congestion, and support facilities (normal and emergency) available.

Section I presents a general description of tropical cyclones and the environmental phenomena associated with them. Discussion of ship performance under tropical cyclone conditions and details of tropical cyclone warnings are also given.

Subsequent sections present information about a particular geographical area including details of individual ports and harbors, local topographical influences on tropical cyclones, and helpful guidelines for the decision-making process of whether to sortie or remain in port.

On the basis of the studies conducted in the development of this Handbook, each port considered has been rated for its suitability as a typhoon haven. These ratings are given in Table 1.



1 - Otaru	13 - Naha	25 - Palau
2 - Muroran	14 - Maizuru	26 - Cebu
3 - Ominato	15 - Hakodate	27 - Manila
4 - Hachinohe	16 - Pohang	28 - Subic Bay
5 - Yokohama	17 - Pusan	29 - Hong Kong
6 - Yokosuka	18 - Chinhae	30 - Auckland
7 - Numazu	19 - Inchon	31 - Fremantle
8 - Kure	20 - Chilung	32 - Surabaya
9 - Iwakune	21 - Kaohsiung	33 - Jakarta
10 - Kagoshima	22 - Saipan	34 - Diego Garcia
11 - Sasebo	23 - Tinian	35 - Colombo
12 - Buckner Bay	24 - Guam	36 - Karachi

Figure 1. Locator map of western Pacific and Indian ocean ports evaluated as typhoon havens.

Table 1. Ratings of western Pacific and Indian ocean ports evaluated as typhoon havens.

GUAM	
APRA HARBOR	POOR
TAIWAN	
KAOHSIUNG	POOR
CHILUNG (KEELUNG)	POOR
HONG KONG	
HONG KONG HARBOR	POOR
JAPAN	
YOKOSUKA	GOOD
NUMAZU OPERATING AREA	POOR
IWAKUNI	MARGINAL
(but has easily accessible anchorages close by which are considered good)	
KURE	GOOD
SASEBO	GOOD
(except for carriers)	
KAGOSHIMA	POOR
BUCKNER BAY, OKINAWA	POOR
NAHA, OKINAWA	POOR
MURORAN	POOR
HACHINOHE	POOR
MAIZURU	GOOD
(except for large ships)	
OTARU	POOR
HAKODATE	POOR
OMINATO	POOR
YOKOHAMA	POOR
(Yokosuka a good option)	
PHILIPPINE ISLANDS	
SUBIC BAY	MARGINAL TO POOR
MANILA	POOR
CEBU	POOR

Table 1 (con't)

KOREA	
INCHON	POOR
(unless shelter is available in the tidal basin; then it would be considered a good haven)	
PUSAN	POOR
CHINHAE	MARGINAL
(but has easily accessible anchorages close by which are considered good)	
POHANG	POOR
SRI LANKA	
COLOMBO	GOOD
PAKISTAN	
KARACHI	MARGINAL
NEW ZEALAND	
AUCKLAND	GOOD TO MARGINAL
AUSTRALIA	
FREMANTLE	MARGINAL
(unless shelter is available in Cockburn Sound or the inner harbor; then it would be considered good)	
DIEGO GARCIA	
DIEGO GARCIA HARBOR	POOR
PALAU	POOR
SAIPAN	POOR
TINIAN	POOR
(but marginal for small ships)	
INDONESIA	
JAKARTA	UNAFFECTED
SURABAYA	UNAFFECTED

V JAPAN

1. GENERAL

Japan is an island nation in the western part of the North Pacific off the eastern coast of the Asiatic mainland consisting of a chain of islands extending in an arc from northeast to southwest. The four main islands of Japan from north to south are Hokkaido, Honshu, Shikoku and Kyushu. Hundreds of smaller islands lie off the coasts of the main ones.

Honshu is the largest of the main Japanese Islands. Yokosuka, a major port city in southeast Honshu, is used continuously by the U.S. Navy. It is currently homeport for a number of SEVENTH FLEET units. Yokohama is just north of Yokosuka. The Numazu Operating Area in south central Honshu is used routinely by the U.S. Navy. Additionally, commercial shipping firms utilize three small harbors in the Numazu area. Iwakuni and Kure are located in the southwestern region of Honshu. Hachinohe and Ominato are located on the northern coast of Honshu and Maizuru on the central western coast.

Kyushu is the third largest and the southernmost major island land mass of Japan. The two major ports of interest for the U.S. Navy on this island are Sasebo and Kagoshima.

The ports of Muroran, Otaru and Hakodate are located on the northernmost island, Hokkaido.

Okinawa is located approximately 350 nmi south of Kyushu and has two major ports of interest to DOD vessels, Buckner Bay and Naha.

A detailed description of the coasts and harbors of Japan can be found in the Sailing Directions (Enroute), Pub. No. 156.

2.0 **YOKOSUKA**

SUMMARY

The conclusion reached in this study is that the port of Yokosuka is a "safe" typhoon haven; a port in which to remain if already there or one in which to seek shelter if at sea when threatened by a typhoon. The primary factors in reaching this conclusion are:

(1) The port provides shelter from wind and sea due to the surrounding land masses.

(2) Wave action induced by typhoons is negligible in most parts of the port.

(3) Storm surge has a negligible effect.

(4) The orientation of the berths and drydocks with respect to the local topography is good.

(5) The extensive experience level and the high degree of competence of Port Services personnel.

(6) The history of the port. Conversations with employees of Fleet Activities, Yokosuka, civilian Japanese authorities, and Japanese Maritime Self Defense Forces (JMSDF) personnel indicate that there is no need for properly moored U. S. Navy, JMSDF, or merchant ships to sortie from the port of Yokosuka during a typhoon.

(7) Except for aircraft carriers, the only situations in which the port would not be a safe haven is when a very intense typhoon ($>$120 kt) passed directly over or within 100 nmi to the northwest of Yokosuka. For aircraft carriers, if a berth shift to drydock 6 is not feasible, a sortie from Yokosuka is recommended when Tropical Cyclone condition of Readiness Three (48 hours) is set for sustained winds of 75 kt or greater at Naval Oceanography Command Facility, Yokosuka.

12. OTARU

SUMMARY

The conclusion reached in this study is that Otaru cannot be considered a haven for ships when the port is threatened by a tropical cyclone or other strong wind event. The reasons for this conclusion include:

(1) The lack of protection in the harbor and resultant vulnerability of moored and anchored ships to strong winds.

(2) The local harbor authority recommendation that all ships sortie when the harbor is threatened by strong winds.

12.1 LOCATION

The Port of Otaru is located at 43°12'N 141°01'E on the western side of Hokkaido, the northernmost of the four main Japanese islands (Figure V-157).

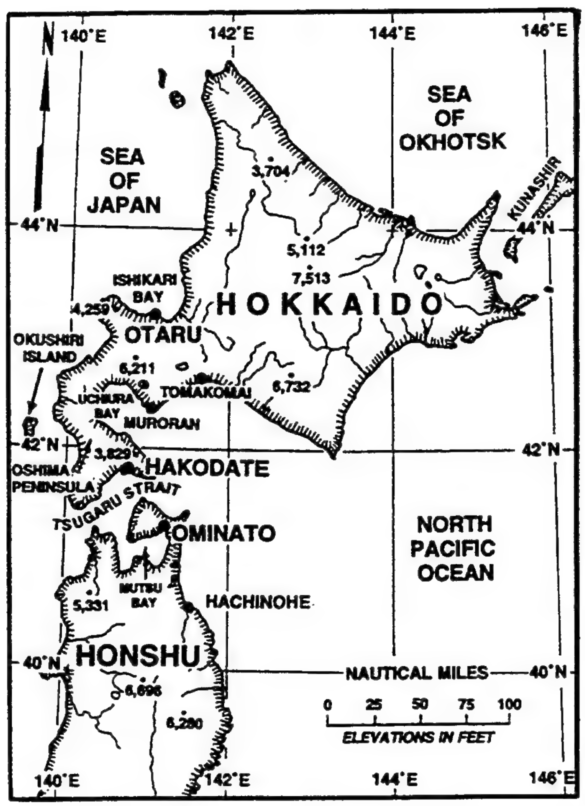


Figure V-157. Location of Otaru on Hokkaido and its position relative to other significant ports in northern Japan.

12.2 OTARU HARBOR

Otaru Harbor is situated on the south shore of Ishikari Bay, and is positioned on the east side of a small, northward extending peninsula (Figure V-158).

The east side of the inner harbor is defined by a 1,684 yd (1,540 m) long, north breakwater; a detached 1,001 yd (915 m) long, center breakwater; and a south breakwater that is 892 yd (816 m) long (Figure V-159). A fourth, 290 yd (265 m) long, detached breakwater extending east-southeastward near the south end of the north breakwater protects the harbor entrance.

A fifth, 110 yd (101 m) long, detached breakwater extending east-southeastward near the south end of the center breakwater protects the relatively narrow passage between the center breakwater and the south breakwater. All breakwaters are approximately 6.5 ft (2 m) high.

OTARU

The harbor is entered through the 219 yd (200 m) wide entrance which passes between the north and center breakwaters. Charted depths in the 547 yd (500 m) long channel leading from the harbor limit to the harbor entrance (Figure V-159) are 49 ft (15 m) or greater. Depths in the inner harbor vary significantly from location to location, with the shallower depths generally confined to the northwestern part of the harbor.

U. S. Navy ships are normally assigned to berths 1 and/or 2 of the 800 yd (732 m) long Katsunai Wharf, which is located in the southern part of the harbor. Charted depths from the harbor entrance to Katsunai Wharf are generally in the range of 33 to 49 ft (10 to 15 m). Depths alongside berths 1 and 2 at Katsunai Wharf were reported to be 24.6 to 39 ft (7.5 to 11.9 m) during a visit by a U. S. Navy ship (FICPAC, 1992). Harbor authorities at Otaru state that Amphibious Command ships of the Blue Ridge class (620 ft long, 19,290 tons) are the largest vessels that Katsunai Wharf can accommodate.

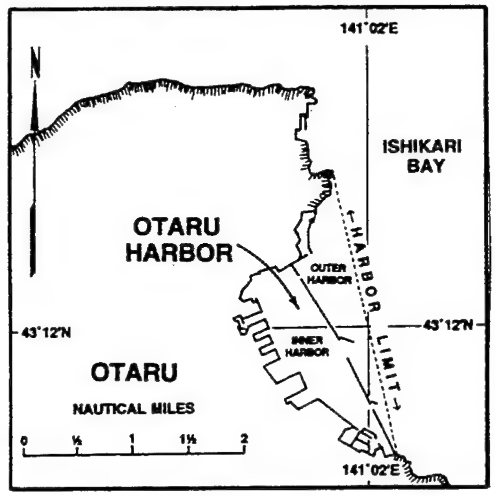


Figure V-158. Location of Otaru Harbor in relation to the adjacent peninsula and Ishikari Bay.

Although not likely, it is possible that U. S. Navy ships may be assigned to Wharf 3, berths 15, 16 and/or 17. According to local harbor authorities and a Japanese harbor chart promoting the use of Otaru Port, alongside depth at the three berths is 29.5 ft (9 m), but DMA Chart 96942 shows depths as shallow as 21 ft (6.4 m) close to berth 15. Japanese Maritime Self Defense Force (JMSDF) ships usually moor to Ironai Wharf, berth 1.

Charted depths from the harbor entrance to approximately 328 yd (300 m) from Wharf number 3 are in the range of 33 to 49 ft (10 to 15 m), but diminish to less than 33 ft (10 m) within 328 yd (300 m) of the wharf.

Otaru has two primary anchorages: a safety/quarantine anchorage outside the breakwaters at the position indicated on Figure V-159, and an anchorage in the inner harbor. The outer anchorage has a sand bottom of unspecified holding quality. The exact location of the inner harbor anchorage is not shown on available charts, but is reported to have a mud bottom with good holding. A Japanese harbor chart indicates a portion of the anchorage is in Section I of the harbor near the 20 meter depth contour shown on Figure V-159, and another is northeast of Katsunai Wharf in Section II of the

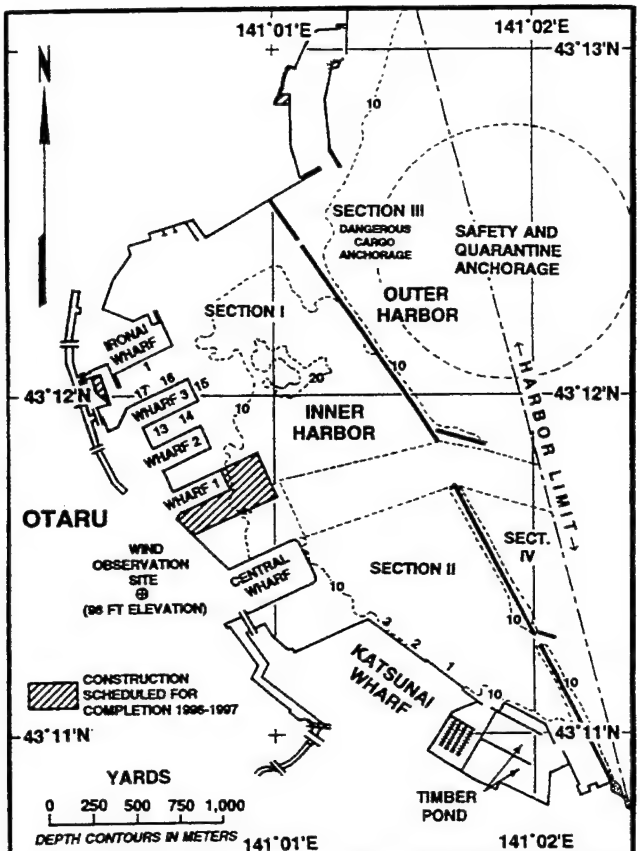


Figure V-159. Otaru Harbor.

harbor. Local authorities state that U. S. Navy ships will always be assigned berths at the wharves and not be required to use the anchorages.

The Japanese harbor chart also shows an anchorage for ships with dangerous cargo. As indicated on Figure V-159, it is located about 350 yd east of the north breakwater in depths of 33-36 ft (10-11 m) in Section III of the harbor.

Tidal range at the port is minimal, about 1.1 ft (34 cm). Local harbor authorities state that currents at Otaru are essentially non-existent and pose no problem to harbor operations.

12.3 HARBOR FACILITIES

Although pilotage is not mandatory, the use of harbor pilots is recommended when entering and leaving the port. Otaru harbor has two 2,600 hp tug boats available for use. No significant ship repair facilities exist at the port, but emergency deck, engine and electrical repairs can be arranged.

12.4 TOPOGRAPHY

Most of the terrain adjacent to Otaru is rugged. Elevations commonly exceeding 2,000 ft (610 m) in elevation southeast clockwise through west of the port provide limited protection from winds from those directions (Figure V-160). The highest peak within a 10 nmi radius of Otaru is Mount Yoichi, a 4,882 ft (1,486 m) peak located south of the Port.

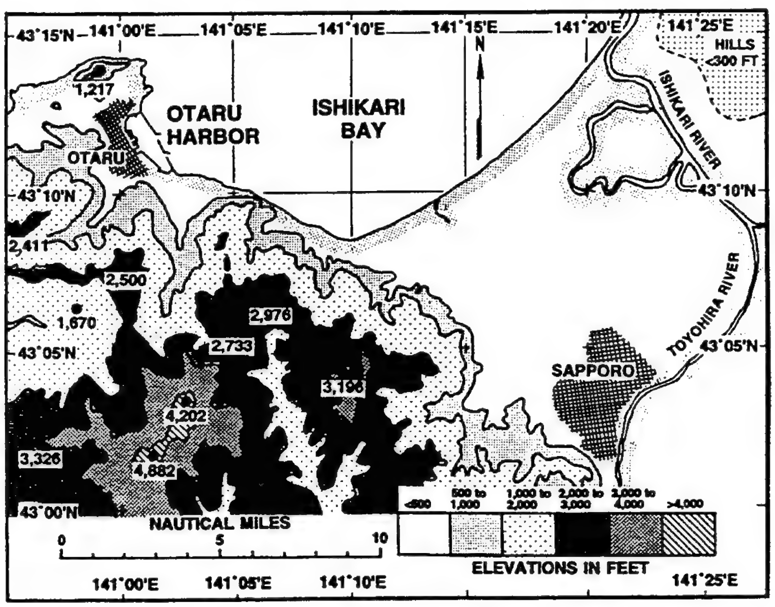


Figure V-160. Topography adjacent to the Port of Otaru.

A broad valley extends from the southeast coast of Ishikari Bay across Hokkaido to near Tomakomai on the Pacific Ocean. The valley provides an access for southeasterly winds to reach Ishikari Bay. However, southeasterly winds do not pose a major threat to the port due to its location west of the valley's southeast to northwest axis. Winds from the north quadrant bring the worst conditions to the port. Winds from north clockwise through northeast pose the greatest threat because they reach the port with their full open-ocean velocities.

OTARU

12.5 TROPICAL CYCLONES AFFECTING OTARU

12.5.1 Tropical Cyclone Climatology at Otaru

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Otaru is considered to represent a threat to the port. Table V-39 contains a descriptive history of all tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992. Unless otherwise indicated, all of the tropical cyclone statistics utilized in this report for storms passing within 180 nmi of Otaru are based on the data set used to compile Table V-39.

Table V-39. Descriptive history of the 33 tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992. Forward speed at closest point of approach (CPA) is in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	KITTY	1949	SEP	1	9	42	31 (W)	024/34.1
2	JANE	1950	SEP	3	8	42	66 (SE)	043/29.5
3	KEZIA	1950	SEP	14	9	50	69 (SE)	058/48.6
4	KAREN	1952	AUG	19	8	40	4 (SSW)	085/22.0
5	TESS	1953	SEP	26	15	49	155 (SE)	043/27.4
6	KATHY	1954	SEP	8	9	33	61 (NW)	030/41.4
7	MARIE	1954	SEP	26	12	60*	40 (NW)	031/51.8
8	LOUISE	1955	SEP	30	15	68	28 (SSE)	051/33.7
9	BABS	1956	AUG	18	9	30	85 (SSW)	012/11.1
10	BESS	1957	SEP	7	9	38	132 (SSE)	069/36.2
11	ALICE	1958	JUL	23	9	50	97 (SE)	032/33.8
12	HELEN	1958	SEP	18	14	40	177 (E)	356/35.1
13	GEORGIA	1959	AUG	15	7	42	153 (NW)	041/ 4.2
14	SARAH	1959	SEP	18	14	70	7 (SSE)	029/20.8
15	VERA	1959	SEP	27	15	75	165 (SSE)	065/32.2
16	VIRGINIA	1960	AUG	12	10	63	158 (SSE)	072/46.4
17	DELLA	1960	AUG	30	16	55	138 (WNW)	028/30.6
18	NANCY	1961	SEP	16	18	65	19 (SSW)	017/57.4
19	NORA	1962	AUG	3	8	35	138 (SSW)	113/32.8
20	SHIRLEY	1963	JUN	21	4	45	12 (S)	062/19.8
21	WILDA	1964	SEP	25	24	43	156 (SSE)	051/56.4
22	JEAN	1965	AUG	6	16	57	150 (WNW)	008/40.5
23	SHIRLEY	1965	SEP	10	24	53*	19 (NNW)	042/33.0
24	TRIX	1965	SEP	18	25	58	100 (ESE)	034/41.1
25	WILDA	1970	AUG	15	8	45	65 (WSW)	029/38.4
26	ANITA	1970	AUG	22	9	45	168 (WSW)	031/24.5
27	HELEN	1972	SEP	20	20	18	47 (SSE)	069/ 8.7
28	THAD	1981	AUG	23	15	48	20 (N)	006/49.3
29	ROGER	1989	AUG	28	20	40	31 (ESE)	023/17.2
30	ZOLA	1990	AUG	23	14	45	88 (SSE)	071/34.6
31	CAITLIN	1991	JUL	30	9	38	155 (NW)	038/20.5
32	MIREILLE	1991	SEP	28	21	60*	92 (SE)	048/58.3
33	JANIS	1992	AUG	9	11	35	76 (SE)	039/33.8

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 43.2°N, 141.0°E.

Tropical cyclones which affect Japan generally form in the area bounded by 5°N to 30°N and 120°E to 165°E. In response to the seasonal changes of the synoptic environment, the latitudinal boundaries shift poleward during the summer months and then equatorward in winter.

Considering the entire western North Pacific basin, about two-thirds of the tropical cyclones reach at least typhoon intensity at some point in their life cycle. Although there is a positive correlation between the maximum storm intensity and the eventual intensity of the storm at closest point of approach (CPA) to Otaru, the relationship is very weak. Much depends on the track of the storm before it reaches Otaru.

Tropical cyclones are nurtured by a warm marine environment. In this basin maximum storm intensity typically occurs between 20°N and 25°N, where sea-surface temperatures average near 84°F (29°C) during the month of August. After recurvature into the westerlies and the association with a colder environment, tropical cyclones lose their tropical characteristics. In this situation, the size of the circulation usually expands, the speed of the maximum wind decreases, the translational (forward) speed of motion increases and the distribution of winds, rainfall and temperature becomes increasingly asymmetric.

Although tropical cyclones have occurred during all months in the genesis area described in the preceding paragraphs, the primary season for Otaru is during August and September. As shown in Table V-40, tropical storms have passed within 180 nmi of Otaru as early as June, but none has passed during the months of October through May. It can readily be seen that few typhoon-strength storms penetrate the 180 nmi threat radius around Otaru. Approximately 12% (4 of 33) of the total number of storms occurring during the 48-year period of record have been of typhoon strength when at their CPA to Otaru. Those storms occurred during September.

Table V-40. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	0	1	2	13	17	0	0	0	33
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	0	0	4	0	0	0	4
Number of storms less than typhoon intensity at CPA	0	0	0	0	0	1	2	13	13	0	0	0	29
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	—	*	*	043	036	—	—	—	040
Average storm speed (knots) at CPA	—	—	—	—	—	*	*	30	38	—	—	—	34
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

Table V-40 also shows the motion history of the 33 tropical storms and typhoons which passed within 180 nmi of Otaru during the period 1945-1992. The table indicates that the average storm speed at CPA is 34 kt. The reason for the relatively rapid movement lies in the location of Otaru. As shown in Appendix A, most tropical cyclones that pass close to Otaru have already recurved and are moving northeastward under the influence of upper level westerlies. Since many of the storms affecting Otaru are in the acceleration phase, rapid

movement is common. While the average movement for all storms is 040°/34 kt, storms occurring during September have a 38 kt average speed. As shown in Table V-39, it is not uncommon for September storm speeds to exceed 50 kt.

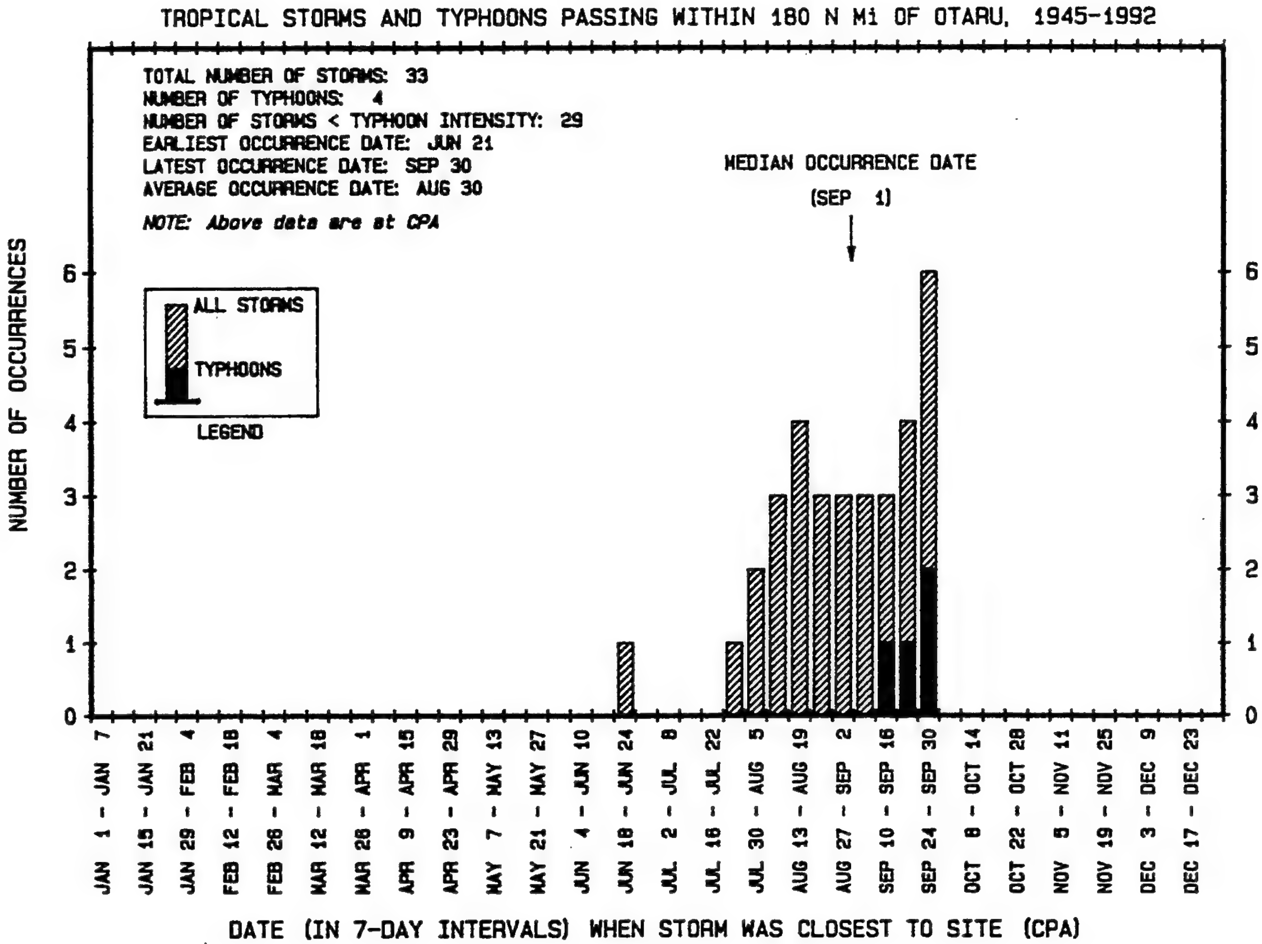


Figure V-161. Monthly distribution of the 33 tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992.

During the 48-year period from 1945 through 1992 there were 33 tropical storms and typhoons that met the 180 nmi threat criterion for Otaru. Figure V-161 shows the monthly distribution of the 33 storms by 7-day periods. The period of peak activity extends from early August through late September.

Figure V-162 depicts the annual distribution of tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992. The designation as a tropical storm or typhoon is based on the intensity of the storm at the time of CPA to Otaru. It is interesting to note that while 21 storms were recorded during the 14-year period 1952-1965, only one storm was recorded during the 16-year period 1973-1988.

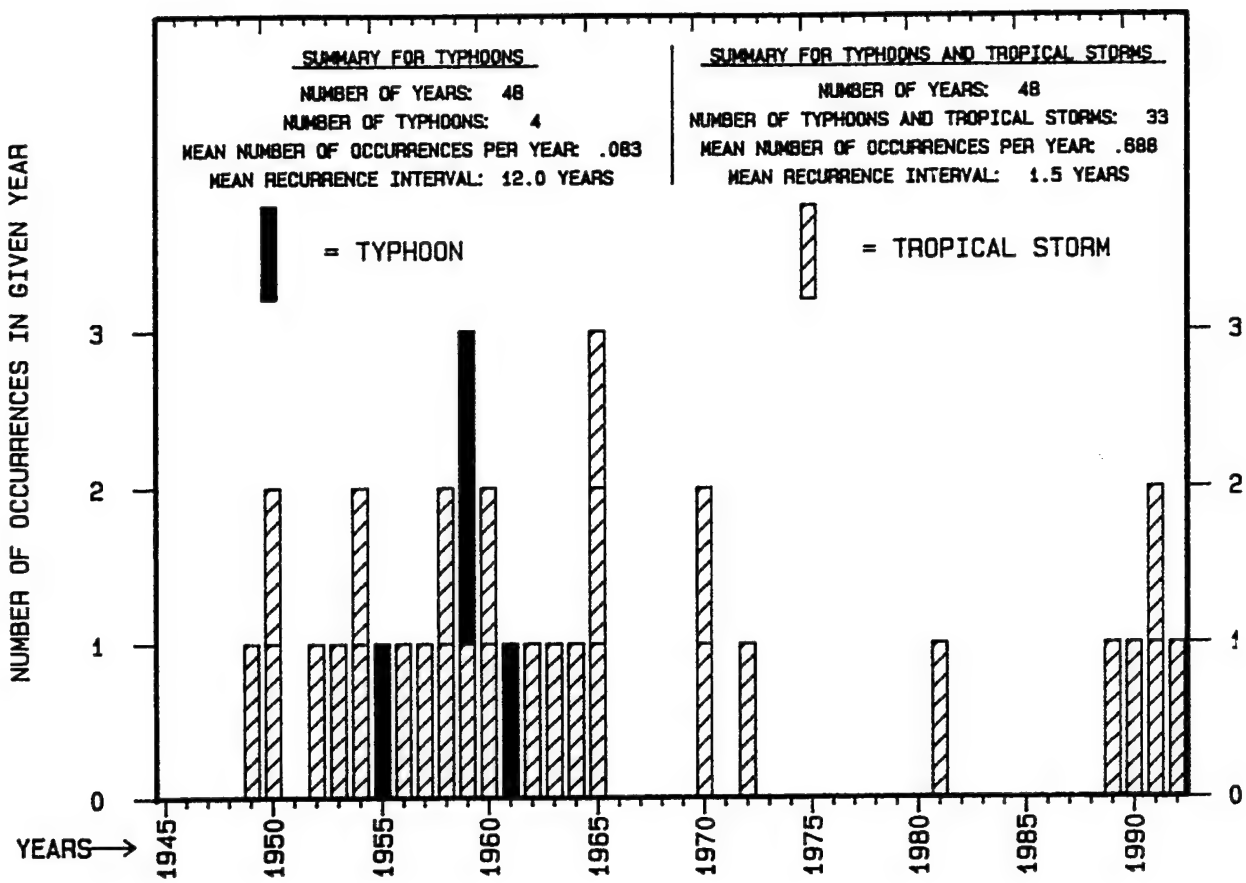


Figure V-162. Chronology of all tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992. Storm intensity is determined at time of closest point of approach (CPA) to Otaru.

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Figure V-163 depicts, on an 8-point compass, the octants from which the 33 tropical cyclones in the data set approached Otaru. Over 97% (32 of 33) of the storms approached Otaru from the south, southwest or west octants. The approach direction is determined at CPA, and may not represent the initial approach direction of the tropical cyclone toward Otaru.

Because of climatological considerations, there are preferred areas of the western North Pacific basin from which tropical cyclones eventually affect Otaru. However, there are some tropical cyclones which, even though they traverse these preferred areas, do not affect Otaru. Also, as might be expected, there are seasonal shifts to these preferred areas.

Figures V-164 and V-165 address the probability of tropical cyclones affecting Otaru. Using a grid system, a tabulation was made of the total number of tropical cyclones passing through a given grid area regardless of whether they eventually passed within 180 nmi of Otaru. A further tabulation was made of those storms which did eventually pass within that distance from Otaru. After smoothing, these two tabulations were converted into probabilities and contours were drawn to connect points of equal probability.

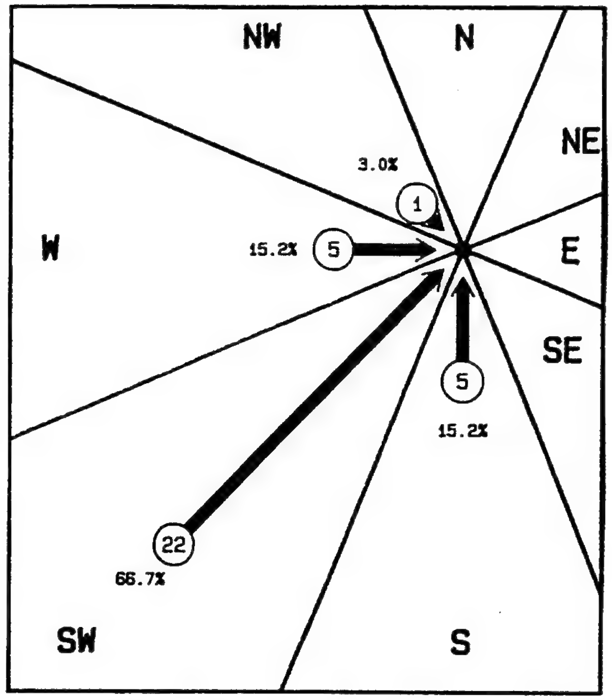

Figure V-163. Directions of approach for 33 tropical storms and typhoons passing within 180 nmi of Otaru during the 48-year period 1945-1992. Length of directional arrow is proportional to the number of storms given in the circles of each octant.

The solid lines on the figures represent a "percent threat" for any tropical cyclone location within the depicted area. The heavy, dashed lines represent the approximate time in days for a system to reach Otaru. For example, in Figure V-164, during the months of July and August a tropical cyclone located at 30°N 145°E has an approximate 5% probability of passing within 180 nmi of Otaru and would reach Otaru in approximately 1-1/2 to 2 days.

A comparison of Figures V-164 and V-165 indicates that there is little difference in threat axes according to time of year. Because of Otaru's northerly location, essentially all of the storms that enter its 180 nmi threat radius have recurved and their movement is being influenced by upper level westerly winds. Consequently, they are moving in a general north to northeasterly direction. To pass within 180 nmi of Otaru, the majority of storms cross the Japanese island of Honshu between 131°E and 140°E and travel northward along the west coast of northern Honshu in the eastern Sea of Japan. A few pass through the Tsushima (Korea) Strait or across Korea and transit the central or eastern Sea of Japan before entering Otaru's threat radius.

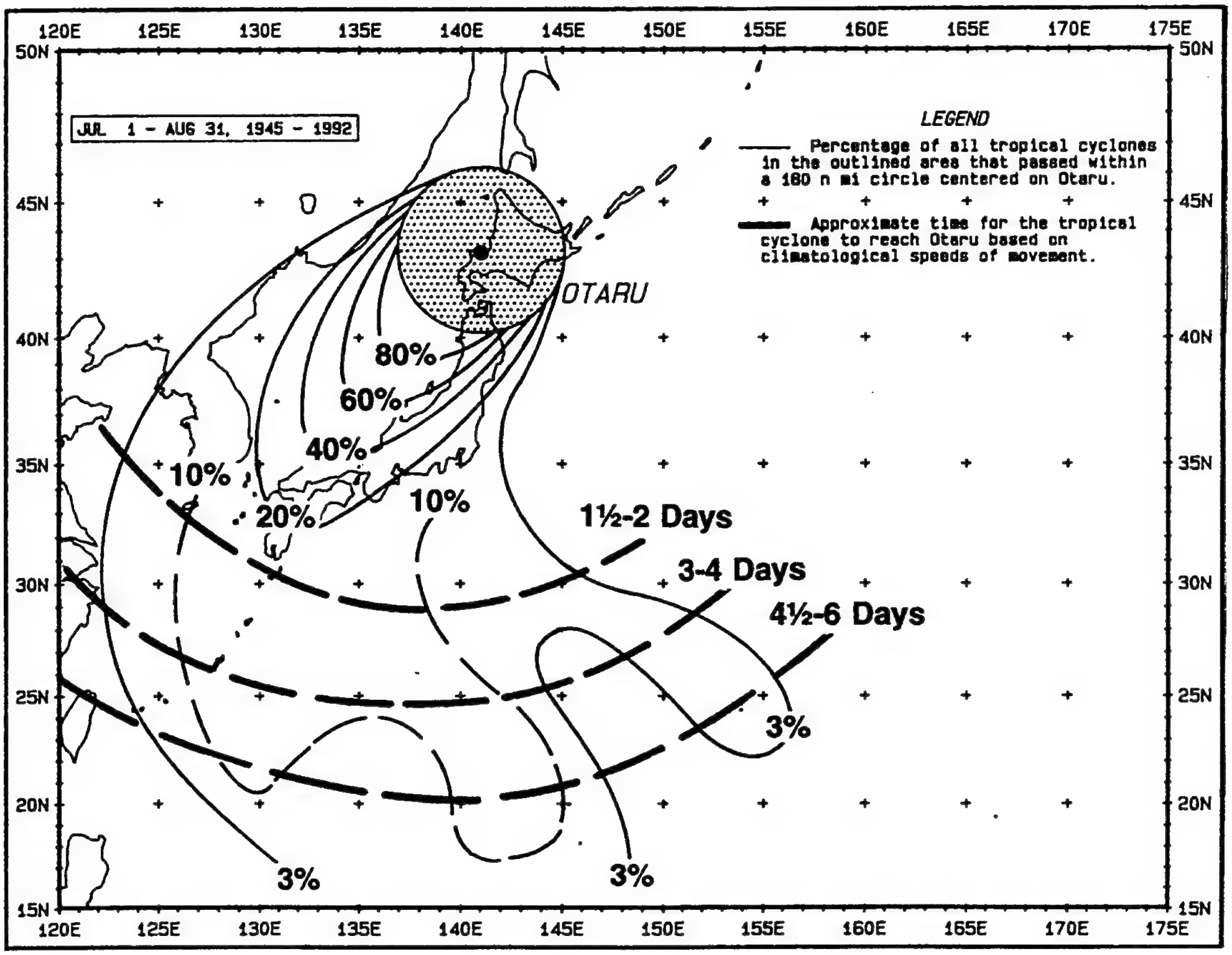

Figure V-164. Probability that a tropical storm or typhoon will pass within 180 nmi of Otaru (circle), and approximate time to closest point of approach, during July and August.

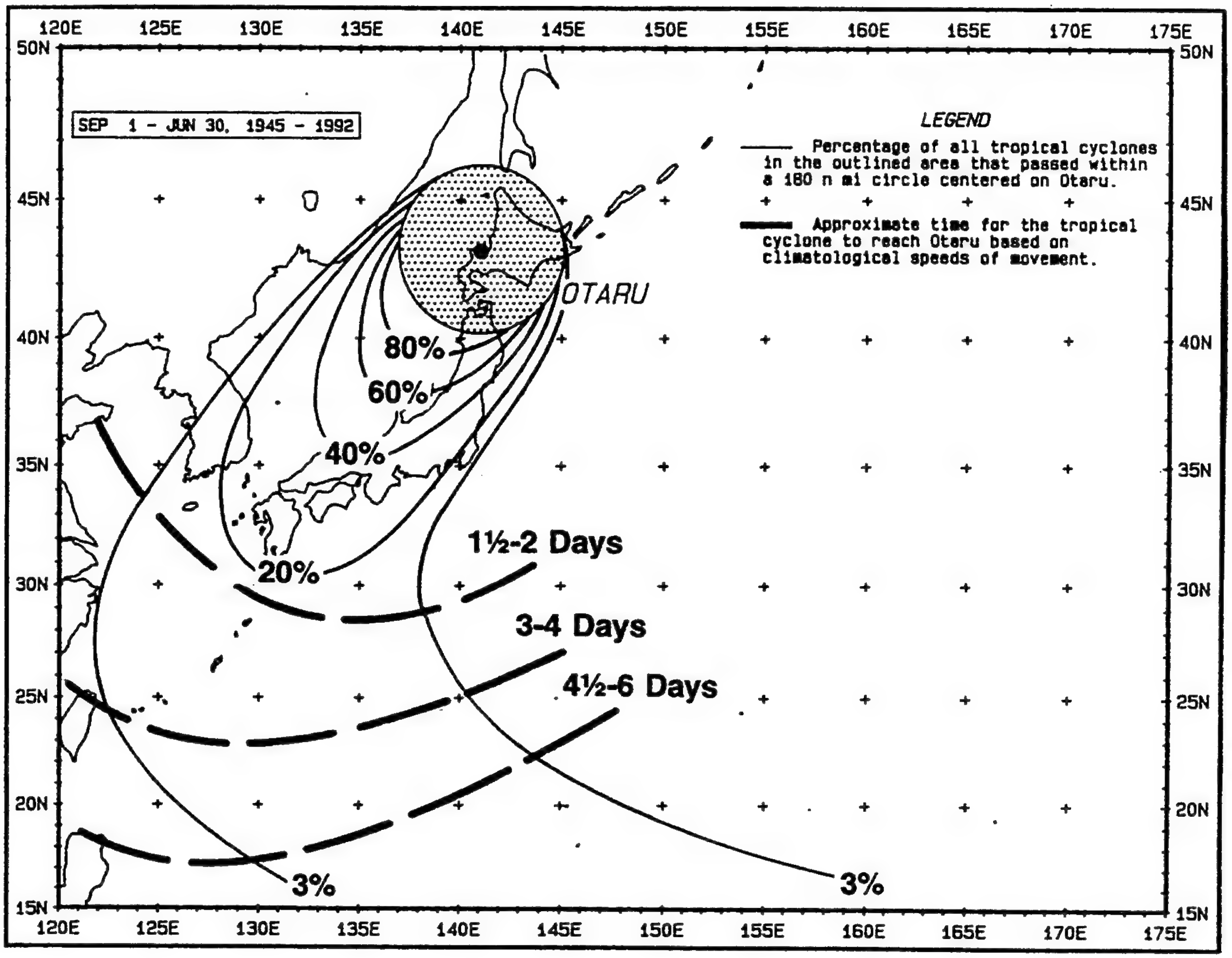

Figure V-165. Probability that a tropical storm or typhoon will pass within 180 nmi of Otaru (circle), and approximate time to closest point of approach, during the months of September and June.

12.5.2 Wind and Topographical Effects

The observation station for the Port of Otaru is located approximately 98 ft (30 m) above mean sea level. It is located on a small hill about 515 yd (470 m) west of the west end of Central Wharf (Figure V-159). Local port authorities consider the observed winds to be representative of conditions in the harbor.

12.5.3 Local Weather Conditions

The data contained in Table V-41 have been selected from observations recorded at Otaru during the passage of the tropical cyclones listed in the table.[1] A total of five tropical storms or typhoons passed within 180 nmi of Otaru during the period 1989 through 1992, the years for which surface observations for Otaru are available. The winds listed in Table V-41 are the maximum winds recorded at Otaru during storm passage.

The two strongest winds listed, west 16 kt for tropical cyclone Roger in 1989 and west 18 kt for tropical cyclone Mirielle in 1991, do not appear to be representative of typical storm circulations. Given the position of each storm relative to the location of Otaru, a more representative direction at Otaru for each storm would be northerly. It is possible that the winds are a result of the pressure gradient west of each storm and not of the primary storm circulation. It should be noted that the available observations did not record any occurrences of winds ≥22 kt during the passage of the storms.

Local harbor authorities state that they believe the greatest wind threat to the port is posed by extratropical cyclones rather than those of tropical origin. Strong post-frontal pressure gradients behind transient extratropical systems bring strong northwest to northeast winds to the port, posing the greatest hazard to vessels in the harbor.

Table V-41. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Otaru 1989-1992. No other observational data are available.

TROPICAL CYCLONE DATA				MOST SEVERE LOCAL CONDITIONS	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND (KT)	WEATHER AND PRECIP AMT./ ACCUM. PERIOD
89/08/28 (ROGER)	023/17	120/31	40	W 16	RAIN SHOWERS 0.94"/UNKNOWN
90/08/23 (ZOLA)	071/35	155/88	45	E 1	RAIN SHOWERS AMT. MISSING
91/07/30 (CAITLIN)	038/20	312/155	38	ESE 8	LIGHT RAIN TRACE/24 HRS
91/09/28 (MIRIELLE)	048/58	141/92	60	W 18	LIGHT RAIN 0.43/UNKNOWN
92/08/09 (JANIS)	039/34	131/76	35	E 13	LIGHT RAIN 0.24/UNKNOWN

[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

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Figures V-166 and V-167 show tracks and track segments of tropical cyclones considered to have a high probability of having produced sustained winds ≥22 kt and ≥34 kt over water near Otaru during the 49-year period 1945-1993. It should be noted that the two figures are derived from theoretical calculations because real-time observational data are available only for the 4-year period 1989-1992. Figures V-166 and V-167 are based on: (1) storm intensity (maximum wind near center), (2) distance of the storm center from Otaru, (3) bearing of the storm from Otaru, (4) translational speed of the storm, and (5) frictional characteristics of the terrain between the storm and Otaru.

The beginning and end points of the arrows in Figures V-166B and V-167B show the positions of the tropical cyclone centers when sustained winds ≥22 kt and ≥34 kt would, theoretically, have begun and ended over water near Otaru.

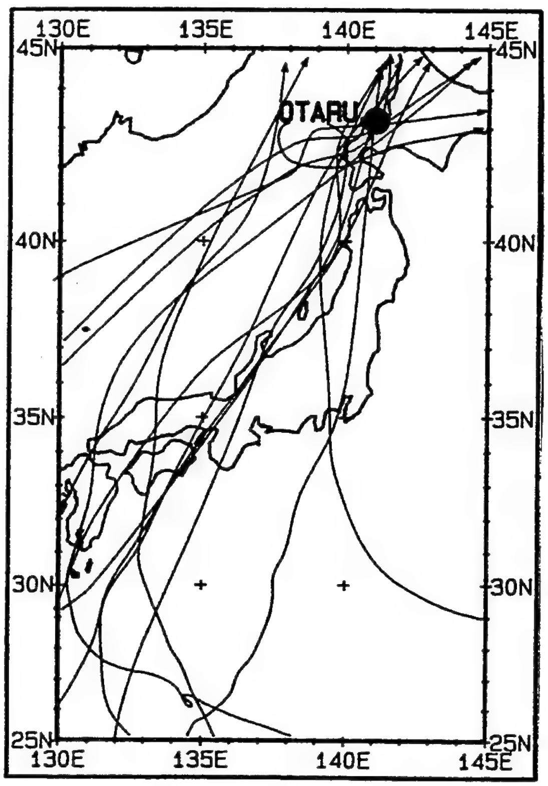

Figure V-166A

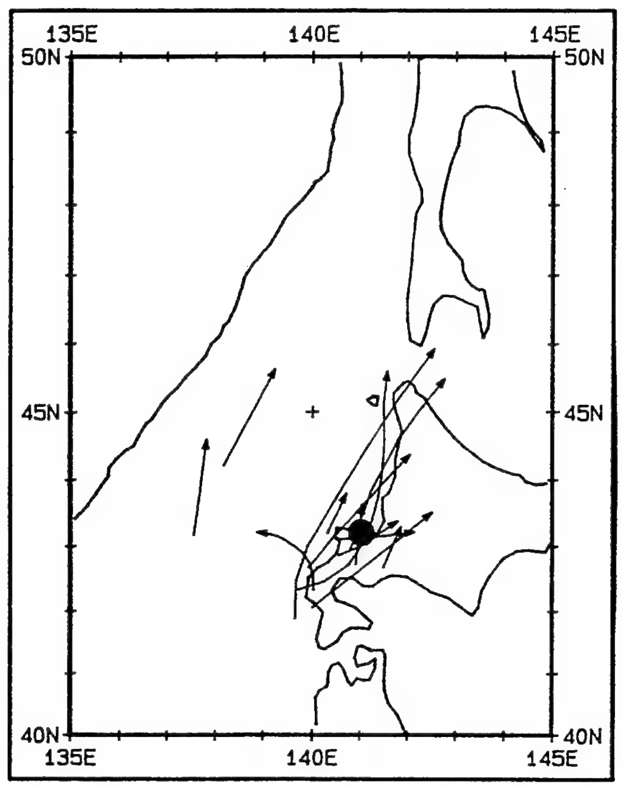

Figure V-166B.

Figure V-166. Tropical cyclones with a high probability of having produced sustained winds ≥22 kt over water near Otaru during the 49-year period 1945-1993. Figure V-166A shows tracks of the 13 high probability tropical cyclones, while Figure V-166B shows track segments of the same storms when ≥22 kt winds were most likely to have occurred over water near Otaru. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

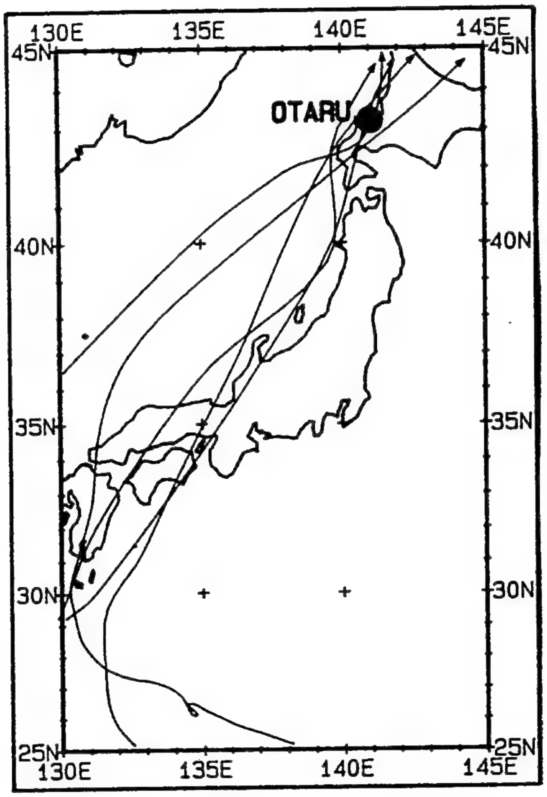

Figure V-167A

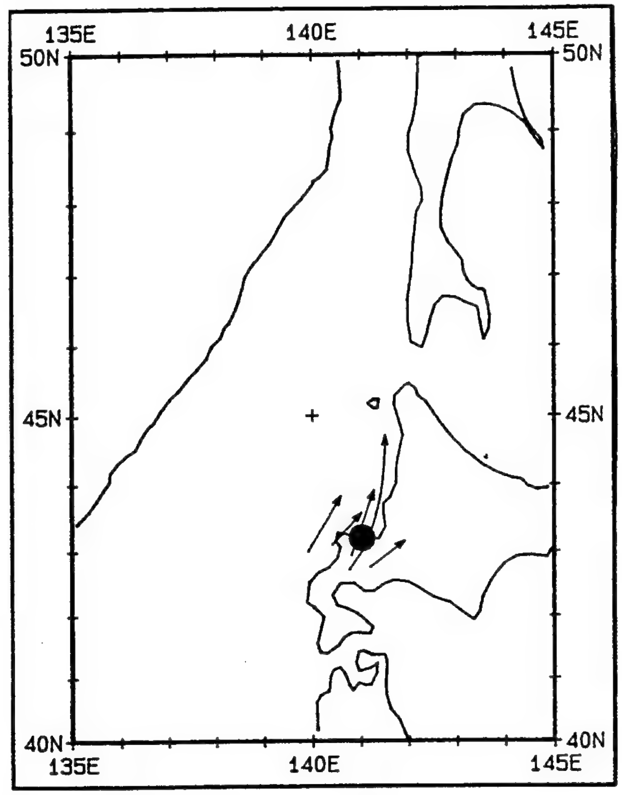

Figure V-167B.

Figure V-167. Tropical cyclones with a high probability of having produced sustained winds ≥34 kt over water near Otaru during the 49-year period 1945-1993. Figure V-167A shows tracks of the five high probability tropical cyclones, while Figure V-167B shows track segments of the same storms when ≥34 kt winds were most likely to have occurred over water near Otaru. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

12.5.4 Wave Motion

The Port of Otaru is exposed and vulnerable to wave motion when winds are from northwest clockwise through northeast. Local authorities state that the maximum wave height experienced in the outer harbor near the entrance to the inner harbor is 10 ft (3 m), and is considered to be a rare occurrence. Most wave energy is effectively blocked by the extensive breakwater system. However, higher waves break over the tops of the 6.5 ft (2 m) high breakwaters thus creating wave motion of unspecified height in the inner harbor.

12.5.5 Storm Surge

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant

contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

The location of Otaru on north-facing Ishikari Bay and the generally rapid movement of tropical cyclones as they approach Otaru would minimize any storm surge effect associated with tropical cyclone passage. Local harbor authorities were unable to recall any recent storm surge event at the port. They did, however, cite a storm surge of 5.6 ft (1.7 m) that occurred during "Showa 26th year" (1951). Since Table V-39 lists no tropical cyclone passing within 180 nmi of Otaru in 1951, it is possible the surge was related to the passage of a strong extratropical storm circulation.

12.6 THE DECISION TO EVADE OR REMAIN IN PORT

12.6.1 General

The exposure and orientation of the Port of Otaru effectively precludes any decision to remain in the harbor during the passage of a tropical cyclone. As discussed in Sections 12.4 and 12.5 above, the harbor is exposed and vulnerable to wind and waves. Evasion is considered to be the only reasonable option when Otaru is threatened by a tropical cyclone. According to local harbor authorities, ships that have remained in the inner harbor during past strong northeasterly wind events have had 3-1/2 inch (90 mm) mooring lines part due to wind stress. One vessel parted nine lines during a single wind event.

12.6.2 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when his/her ship is exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/JTWC) Guam tropical cyclone warnings, and a basic understanding of weather will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures V-164 and V-165, discussed earlier, address the probability of existing tropical cyclones later affecting Otaru. Figures V-168 and V-169 have been prepared as additional aids for the commander to use when evaluating a given situation. In contrast to Figures V-164 and V-165, Figures V-168 and V-169 consider only those storms which later passed within 180 nmi of Otaru. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered as an <u>average</u> approach scenario insofar as Otaru is concerned. It must be stressed that the other 50% of the storms which later affect Otaru will be <u>outside</u> of these bounds. Another important factor is that the actual

NPMOCW/ JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures V-168 and V-169.

The relative distance between the time arcs, coupled with the orientation of the broad arrows, is indicative of the acceleration of tropical cyclones following recurvature. The typical rapid rate of approach to the Otaru area during the last 24 to 48 hours must be considered in all situation analyses.

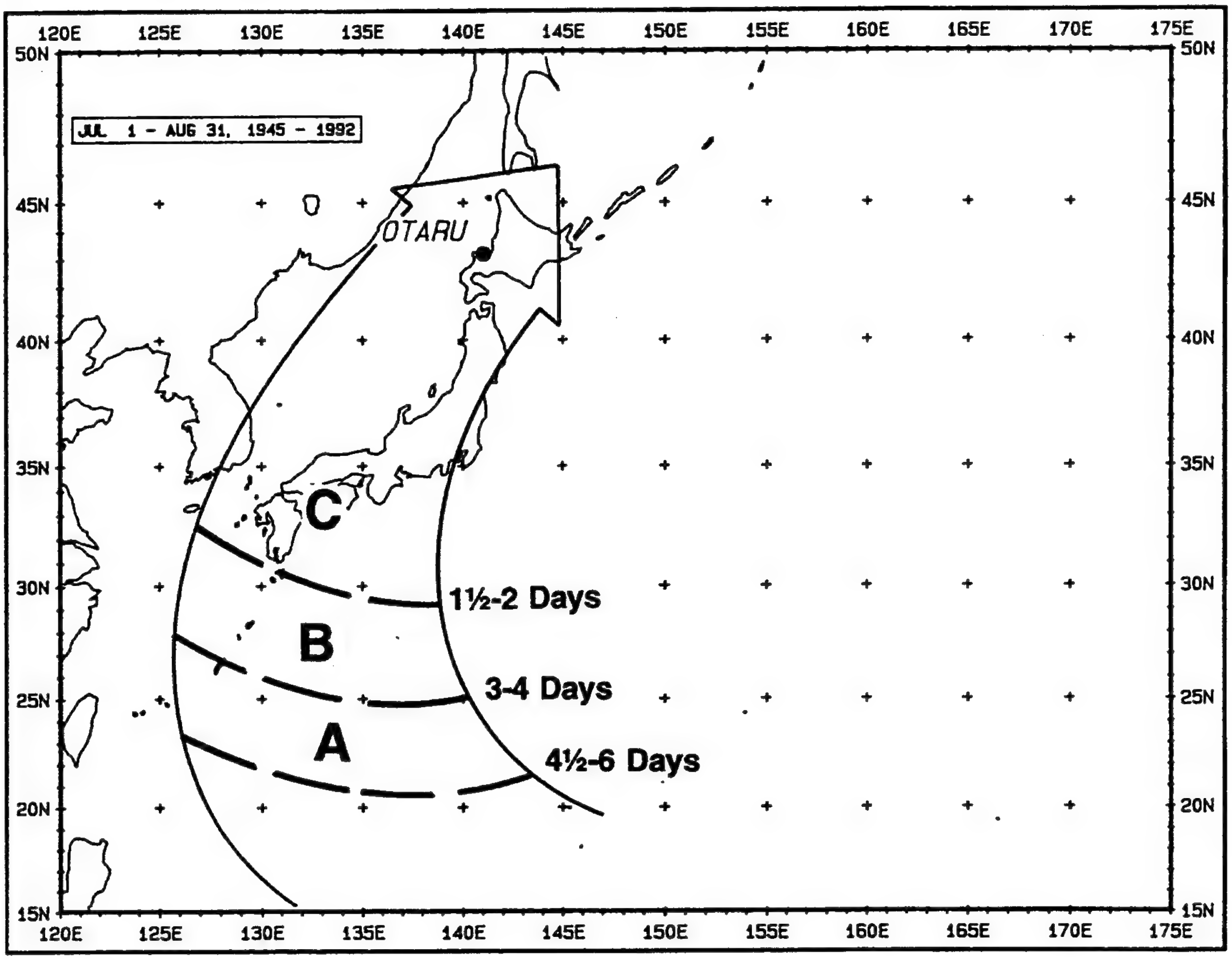

Figure V-168. For the tropical cyclones passing within 180 nmi of Otaru during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Otaru. See Figure V-164 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Otaru.

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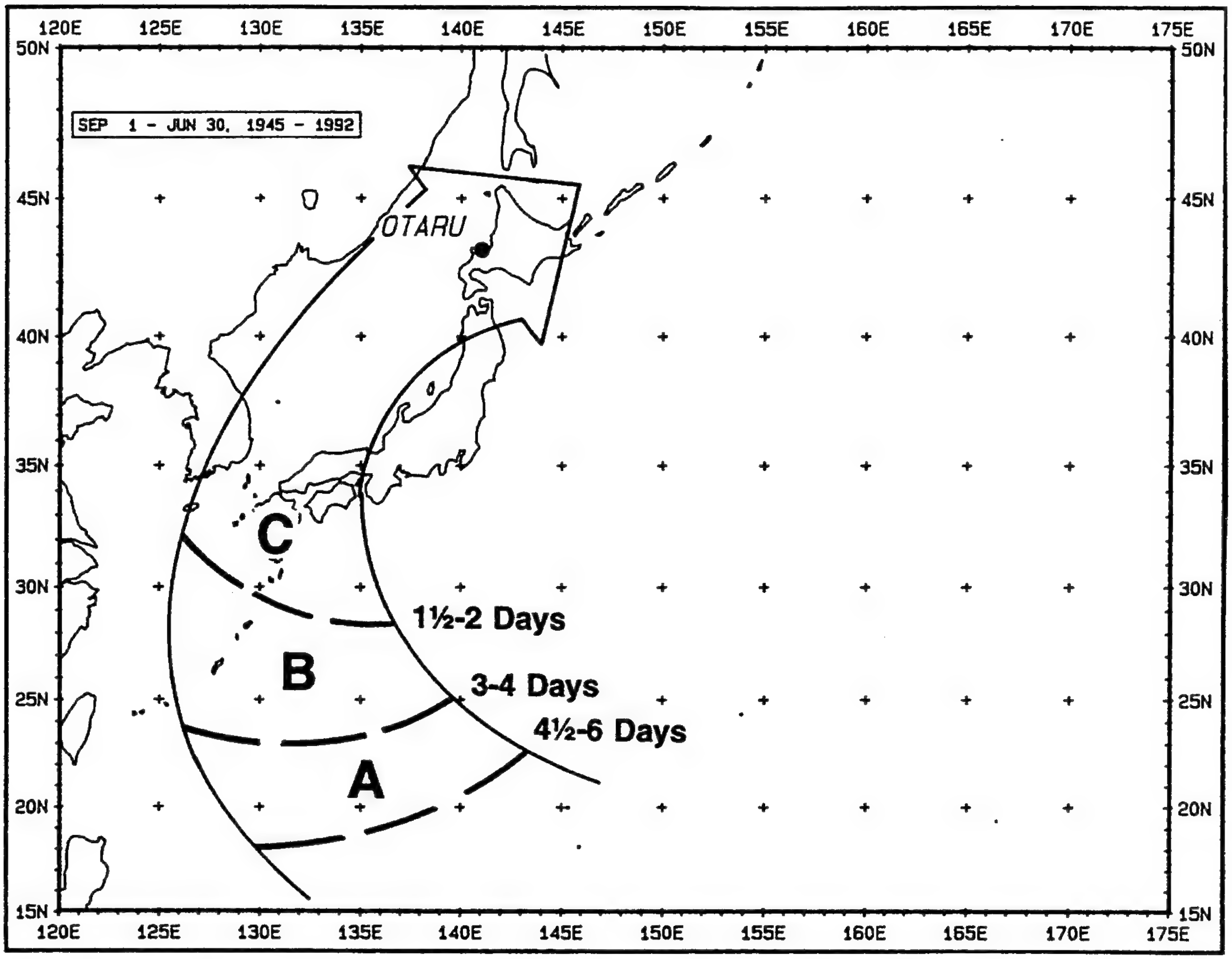

Figure V-169. For the tropical cyclones passing within 180 nmi of Otaru during the months of September and June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Otaru. See Figure V-165 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Otaru.

With the aforementioned restrictions in mind, the following time/action sequence aids, to be used in conjunction with Figures V-168 and V-169, are provided.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast toward Otaru:

a. Review material condition of ship.

b. Formulate plans for expeditious sortie from the harbor and evasion route to be taken in the event the tropical cyclone threatens Otaru.

c. Reconsider any maintenance that would render the ship incapable of getting under way, if need be, within 48 hours.

d. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Otaru (recall that tropical cyclones tend to accelerate rapidly after recurvature).

a. Reconsider any maintenance that would render the ship incapable of getting underway, if need be, within 24 hours.

b. Finalize plans for expeditious sortie from the harbor and evasion route to be taken in the event the tropical cyclone threatens Otaru.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone has entered Area C and is moving toward the Otaru area:

a. Sortie from the harbor, taking an evasion route that will allow the unit to encounter the most favorable weather conditions during the passage of the tropical cyclone.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

12.6.3 Evasion at Sea

Evasion routes at sea may be developed by using NPMOCW/ JTWC tropical cyclone warnings (see Chapter I), and Appendix A (Bi-Weekly Tropical Storm and Typhoon Tracks for the Western North Pacific Ocean) for the period of interest. They should be used in conjunction with Figures V-164 and V-165 (tropical cyclone threat axes and approach times to Otaru). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

Two basic evasion routes are available: (1) remaining in the Sea of Japan, and (2) exiting the Sea of Japan through the Tsugaru Strait (between Hokkaido and Honshu) and proceeding south along the east coast of Honshu. If the tropical cyclone is moving northeastward on a track that would take it east of Otaru, remaining in the Sea of Japan would keep the vessel on the weaker, left side of the storm's circulation thereby avoiding the strongest winds of the storm. However, the ship may be exposed to relatively strong winds from the northwest quadrant as the storm passes and high pressure moves into the Sea of Japan behind the storm's circulation.

If the storm is forecast to pass west of Otaru, moving through the Tsugaru Strait into the Pacific Ocean along the east coast of Honshu should be considered. It must be emphasized that this option has a

potentially serious drawback; if the tropical cyclone should move east of the forecast track, and therefore closer to the ship's evasion route, the ship may encounter the strongest winds of the storm's dangerous semicircle. Any tropical cyclone moving northeastward across the Sea of Japan may have a circulation large enough to bring strong southerly winds to the coastal waters east of northern Honshu. However, the winds should be short-lived because of the historically rapid movement of tropical cyclones when they reach the latitudes of northern Japan.

Regardless of the option chosen, it is of utmost importance to begin the sortie as early as possible. It is approximately 175 nmi from Otaru to the west entrance to Tsugaru Strait, and another 75 nmi to the east coast of Honshu. At a steaming speed of 20 kt, it will take approximately 12 to 13 hours to complete the transit. If the tropical cyclone has recurved before the sortie is commenced and is moving at 30 kt, the storm could be ≥360 miles closer by the time a sortieing vessel reaches the east coast of Honshu. It should be noted that the average speed of movement of tropical cyclones occurring during the period 1945-1992 is 34 kt when at CPA to Otaru (Table V-40), while September storms average an even faster 38 kt. Table V-39 lists four storms that were moving at over 50 kt when at CPA to Otaru.

It must be remembered that tropical cyclones are notoriously difficult to accurately forecast, especially in the recurvature phase; the 48-hour forecast position error may exceed 200 nmi. A storm may be closer to or farther from Otaru than the forecast indicates, or right or left of the storm's forecast track. Each tropical storm or typhoon must be considered as differing from those preceding it. The accompanying synoptic situation must be fully understood. To blindly establish and follow only one technique or rule for avoiding a storm's danger area is not prudent and, in fact, may ultimately place the ship in harm's way.

REFERENCES

FICPAC, 1992: Port Directory for Otaru, Japan, Change 20. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with Mr. Nishino, Chief, Otaru Maritime Safety Office; Mr. Nobuo Horikawa, Chief, Guard and Rescue Division, Otaru Maritime Safety Office; Mr. Hiroyuke Koide, Otaru Maritime Safety Office; and Mr. Suehiro Koukichi and Mr. Nagano Nobutugu, Hydrographic Specialists, First Division, Hydrographic Department, Maritime Safety Agency to obtain much of the information contained in this port evaluation.

13. **HAKODATE**

SUMMARY

The conclusion reached in this study is that Hakodate cannot be considered a haven for ships when the port is threatened by a tropical cyclone or other strong wind event. The reasons for this conclusion include:

(1) The lack of protection from wind for ships moored or anchored in the Inner Harbor.

(2) The lack of protection from wind and seas for ships anchored in the Outer Harbor.

(3) The local harbor authority recommendation that all ships sortie from the harbor when Hakodate is threatened by strong winds.

13.1 LOCATION

The Port of Hakodate is located at 41°47'N 140°43'E near the southeastern end of Oshima Peninsula on Hokkaido, the northernmost of the four main islands of Japan (Figure V-170). Hakodate is positioned on the north side of Tsugaru Strait, which separates the islands of Hokkaido and Honshu.

13.2 HAKODATE HARBOR

Hakodate Harbor is situated on the east side of Hakodate Bay, which is bordered by land on the west, north, and east sides (Figure V-171). The Inner Harbor of the port is bordered by land on the north, east, and south sides.

HAKODATE

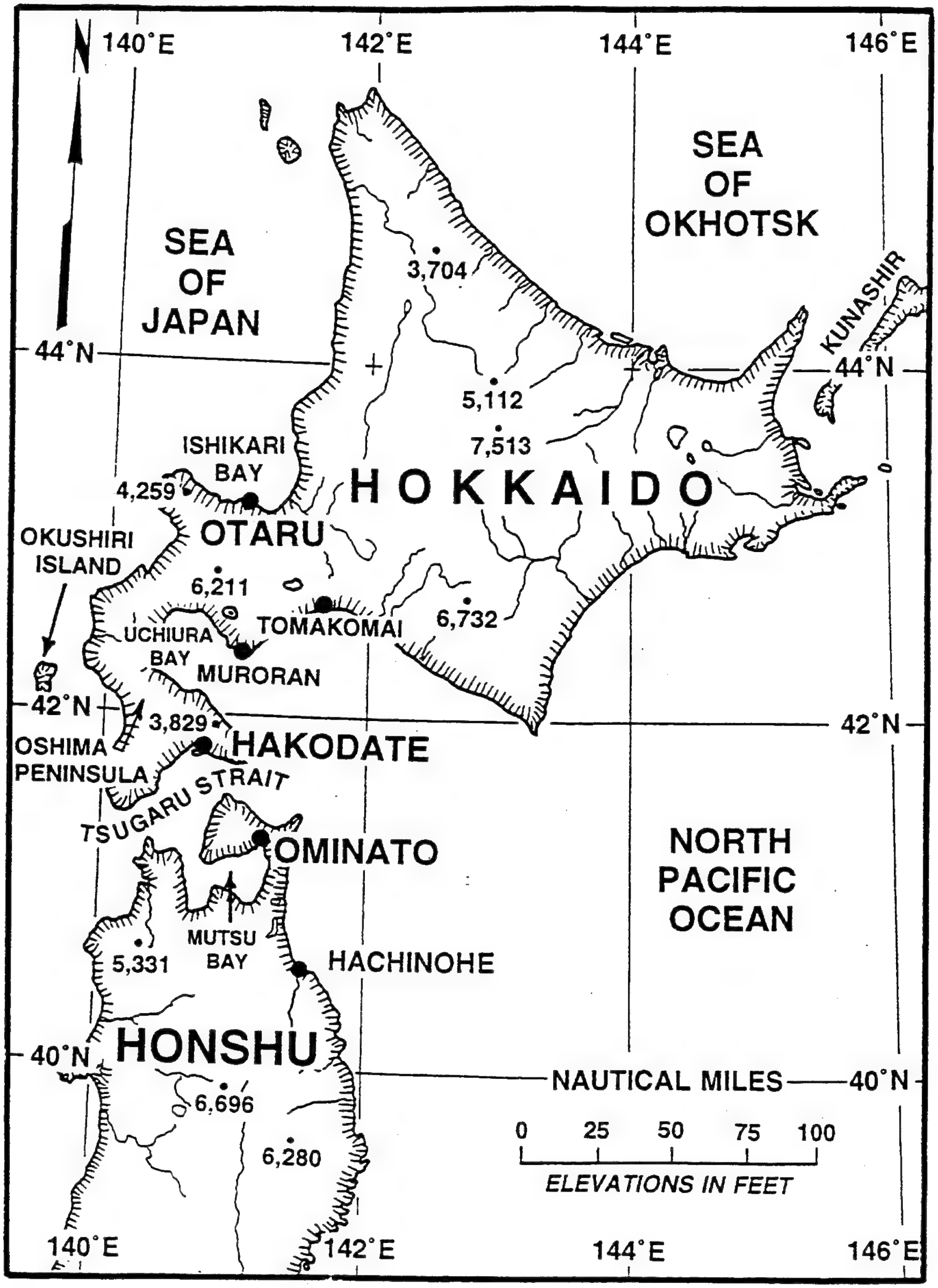

Figure V-170. Location of Hakodate on Hokkaido and its position relative to other significant ports in northern Japan.

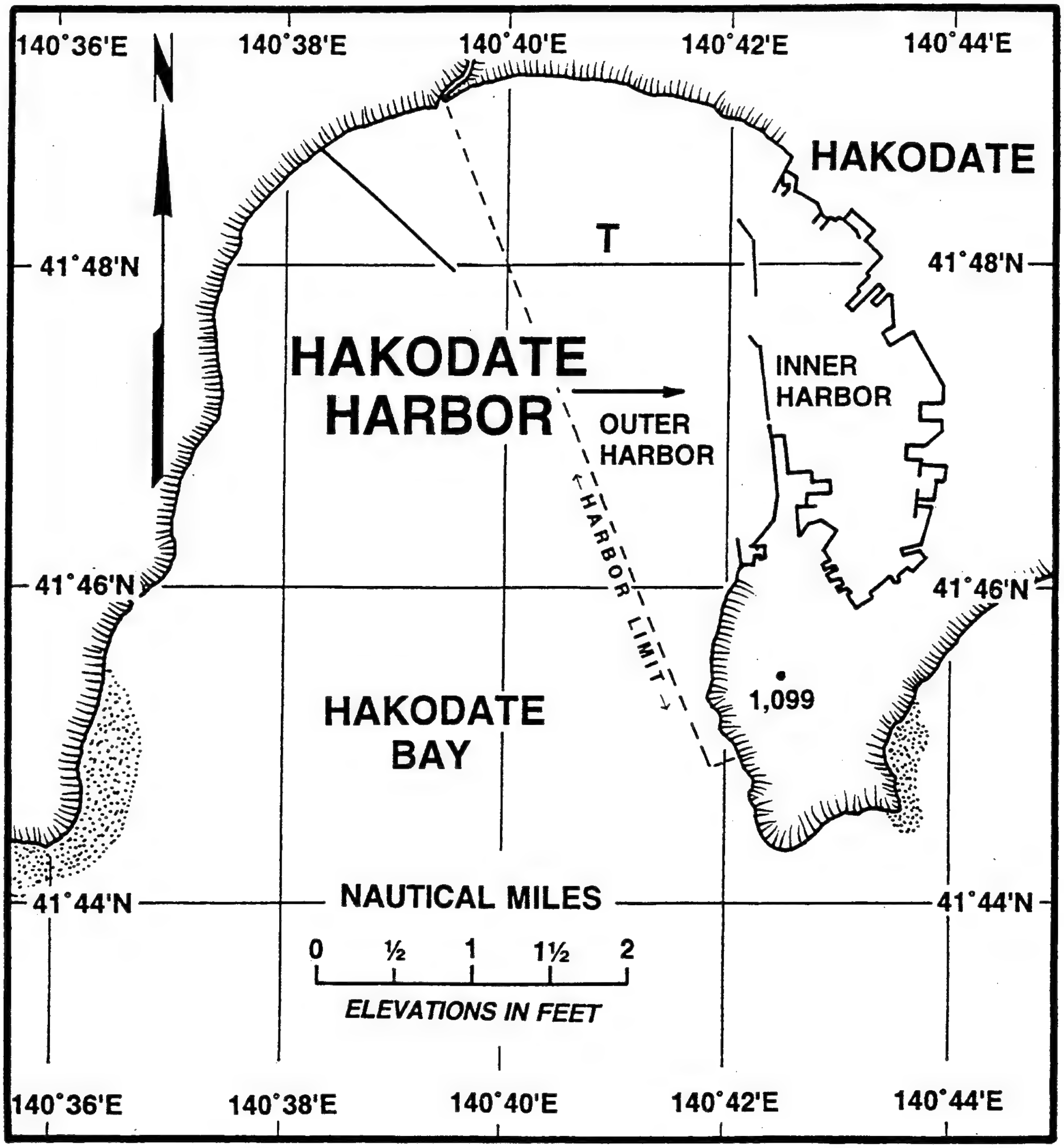

Figure V-171. Location of Hakodate Harbor on Hakodate Bay.

Hakodate harbor is comprised of an Inner Harbor and an Outer Harbor, which are subdivided into six sections. Sections 1 through 4 are located in the Inner Harbor, and Sections 5 and 6 are in the Outer Harbor (Figure V-172).

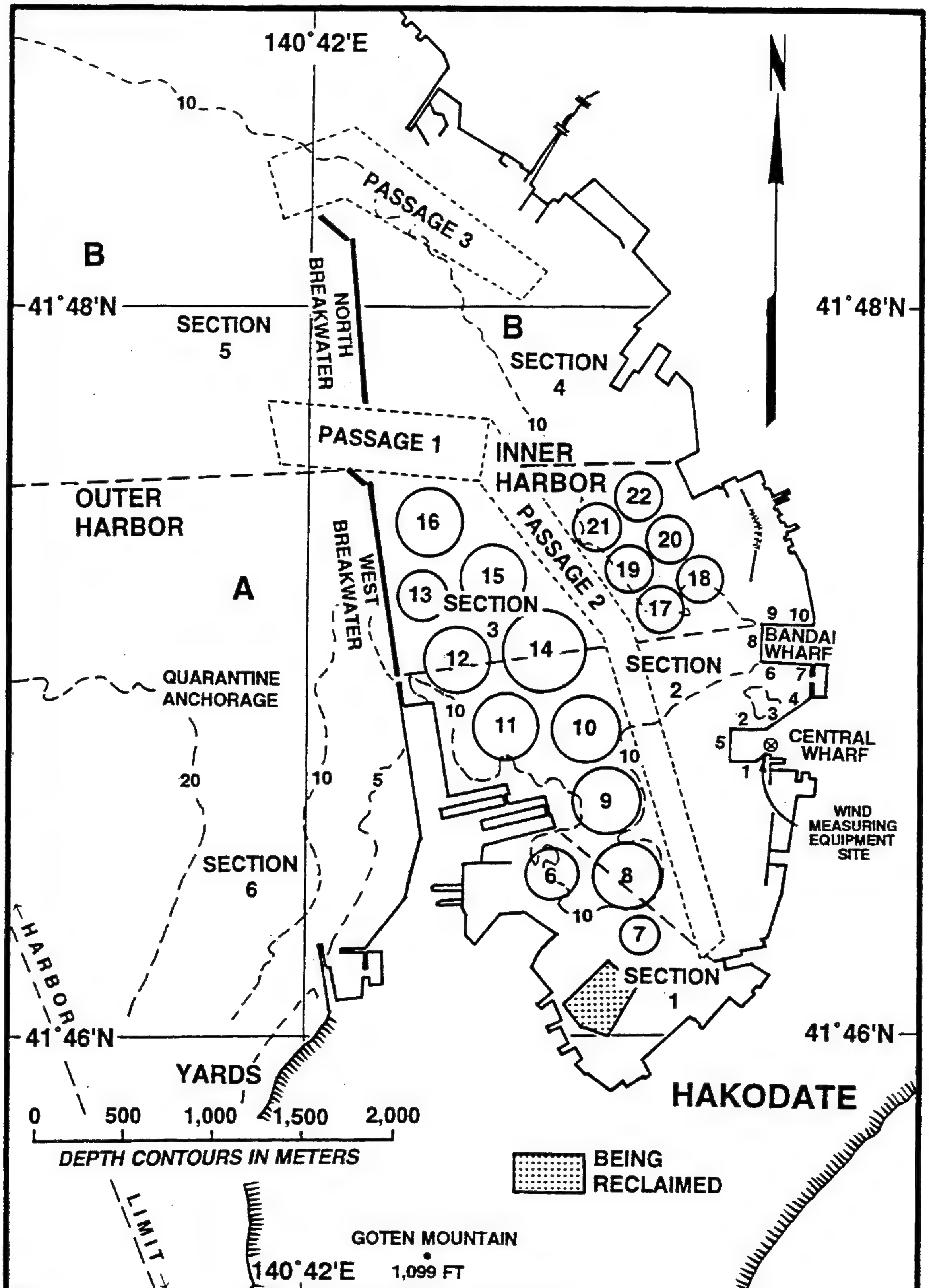

Figure V-172. Hakodate Harbor.

The west side of the Inner Harbor is formed by two breakwaters, the North Breakwater and West Breakwater. Two shorter breakwaters provide additional protection to facilities in the harbor and the harbor entrances. One extends northwestward from the north end of the North Breakwater, and a second, shorter one extends northwestward from the north end of the West Breakwater. All breakwaters were estimated to be 6.5 to 10 ft (2 to 3 m) high by visual observation during a 1993 port visit.

The Inner Harbor has two 372 yd (340 m) wide entrances. Passage 1, the primary entrance to the port, enters the harbor between the North and West Breakwaters. The east end of Passage 1 abuts on the northwest end of Passage 2. Passage 2 is a gradually narrowing Inner Harbor fairway that is used exclusively by ocean-going ferry traffic proceeding to/from a railroad ferry dock located in the southern part of the harbor (FICPAC, 1988). Passage 3 enters the harbor at the north end of the North Breakwater. Passage 3 is used primarily by large maritime ferries which berth in the north end of the Inner Harbor. Local harbor authorities state that ferries enter and leave the port frequently. Because they operate on a closely timed schedule, the ferries will not give way to other vessels in the harbor passages.

U. S. Navy ships to 30,000 GWT may moor to the west end of Bandai Wharf or go to anchor. Charted depths at the 590 ft (180 m) long Berth 8 at the west end of Bandai Wharf are in the 29.5 to 32.8 ft (9 to 10 m) range. Smaller ships will likely be assigned to moorage at Central Wharf, berth #1. A U. S. Navy ship that moored to Central Wharf in 1986 reported depths at the berth exceeded charted depths (FICPAC, 1988). The minimum reported depth was 29.5 ft (9 m) at low tide, which resulted in 7 ft (2.1 m) under the sonar dome on the FF-1052 class frigate.

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It is estimated that the port can accommodate three DD-type alongside moored vessels at one time (FICPAC, 1988).

During a 1993 port visit, pier faces at Bandai Wharf and Central Wharf appeared weathered but sound. They have built-in rubber fenders. Some of the older pier facilities in the north part of the harbor suffered considerable damage in an earthquake that ravaged Okushiri Island (Figure V-170) in 1993. Visual inspection during the 1993 port visit showed that some were cracked and two had portions that either were submerged or appeared to be close to submerging due to failed supports.

Hakodate has four primary anchorages, two in the Inner Harbor and two in the Outer Harbor. The safest anchorages are located just west of the West Breakwater and in the south portion of the Inner Harbor. The anchorage west of the West Breakwater, indicated by the letter "A" on Figure V-172, is the anchorage most likely to be used by U. S. Navy ships. In 1986 a U. S. Navy ship reported a depth of 42 ft (12.8 m) on a bottom of unspecified type or holding quality (FICPAC, 1988). The Inner Harbor anchorage is located east and south of the West Breakwater in the numbered positions indicated on Figure V-172. The bottom is reported to be mud with good holding. Depths are about 33 to 39 ft (10 to 12 m), although a U. S. Navy ship reported depths as shallow as 19.7 ft (6 m) (FICPAC, 1988). Charted depths indicate that the 19.7 ft (6 m) depths would likely be found only in anchorage positions 6 and 7.

There are three mooring buoys in the Inner Harbor anchorage that are controlled by the Hakodate city government. There are four buoys indicated on DMA chart 96947, but local authorities stated (September, 1993) that only three buoys exist. Due to its close proximity to an area being reclaimed, buoy 7 may have been removed. The buoys in positions 10 and 14 (Figure V-172) were

sighted during a 1993 port visit, but the third buoy was not noted. Local harbor authorities stated that the largest vessel that can safely use the buoys during strong winds is 15,000 tons. U. S. Navy ships may use the buoys if permission of the Hakodate city government is obtained beforehand.

The two northernmost anchorages, located in Sections 4 and 5 of the harbor, are the most dangerous in hazardous weather. One is located outside the North Breakwater and the other in the northern portion of the Inner Harbor. The approximate position of each anchorage is indicated by the letter "B" on Figure V-172. A sea berth for super tankers is also located west of the north breakwater. Its approximate location is indicated by the letter "T" on Figure V-171.

Pilotage at Hakodate is mandatory for non-ferry traffic. The port has two 3,200 hp tugs and two 2,400 hp tugs available.

According to Hydrographic Department personnel at Otaru, tides at Hakodate have a normal range of 3.7 ft (1.14 m) with negligible currents in and near the harbor. Currents with an easterly set prevail just south of Hakodate in Tsugaru Strait. Velocities of 1.5 to 4 kt are observed about 5 nmi from the port.

13.3 HARBOR FACILITIES

The Hakodate Dock Company has four shipbuilding ways and a large ship repair facility located in the southwest portion of the Inner Harbor. Local harbor authorities state that the likelihood of U. S. Navy ships being able to use the facility is minimal since it is privately owned and usually quite busy. The port has numerous mechanical handling facilities including seven cranes with 200-ton capacities, two floating cranes (one 200-ton

and one 50-ton), and other equipment for handling bulk cargo (FICPAC, 1988).

13.4 TOPOGRAPHY

The Inner Harbor is bounded by land on the north, east and south sides. The most prominent terrain feature close to the port is 1,099 ft (335 m) high Goten Mountain, located on a peninsula just south of the Inner Harbor (Figures V-172 and V-173). Most of the other terrain near the port is low-lying. Outside an approximate 5 nmi radius, the terrain rises significantly. Elevations exceeding 3,609 ft (1,100 m) occur within 9 nmi to the northeast. Elevations exceeding 984 ft (300 m) exist northwest of Hakodate Bay, within 10 nmi of the port.

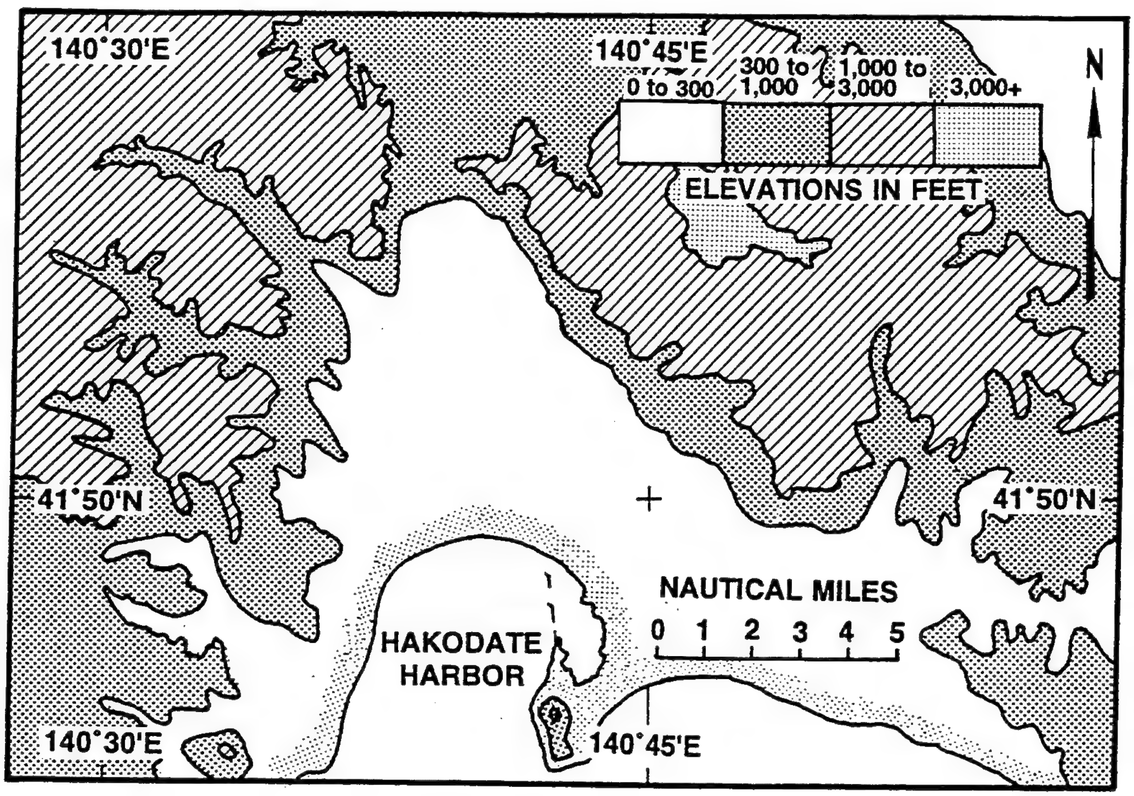

Figure V-173. Topography adjacent to the Port of Hakodate.

13.5 TROPICAL CYCLONES AFFECTING HAKODATE

13.5.1 Tropical Cyclone Climatology at Hakodate

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Hakodate is considered to represent a threat to the port. Table V-42 contains a descriptive history of all 46 tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992. Unless otherwise indicated, all of the tropical cyclone statistics used in this report for storms passing within 180 nmi of Hakodate are based on the data set used to compile Table V-42.

Tropical cyclones which affect Japan generally form in the area bounded by 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment.

Considering the entire western North Pacific basin, about two-thirds of the tropical cyclones reach at least typhoon intensity at some point in their life cycle. In specific reference to the 46 tropical cyclones listed in Table V-42, all except Ruby of 1985 reached typhoon intensity at some point in their history. Indeed, the intensity of 16 of the listed storms reached what is referred to as <u>super-typhoon</u> intensity (at least 130 kt) earlier in their life cycle. Although there is a positive correlation between the maximum storm intensity and the eventual intensity of the storm at CPA to Hakodate, the relationship is very weak. Much depends on the track of the storm before it reaches Hakodate.

Table V-42. Descriptive history of the 46 tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	KITTY	1949	SEP	1	9	43	49 (WNW)	019/34.9
2	JANE	1950	SEP	3	8	44	24 (SSE)	040/30.3
3	KEZIA	1950	SEP	14	9	52	14 (NE)	078/52.6
4	KAREN	1952	AUG	19	8	40	80 (N)	085/22.0
5	TESS	1953	SEP	25	15	52	111 (SE)	031/32.5
6	KATHY	1954	SEP	8	9	37	93 (NW)	030/41.9
7	MARIE	1954	SEP	26	12	63*	48 (W)	358/37.6
8	LOUISE	1955	SEP	30	15	73	36 (WNW)	051/34.1
9	OPAL	1955	OCT	20	19	38	174 (SE)	038/53.7
10	BABS	1956	AUG	18	9	31	35 (W)	013/11.1
11	BESS	1957	SEP	7	9	39	59 (SSE)	059/36.9
12	ALICE	1958	JUL	23	9	52	67 (ESE)	018/38.2
13	IDA	1958	SEP	27	15	29	144 (ESE)	028/19.1
14	GEORGIA	1959	AUG	14	7	57	162 (W)	351/38.0
15	SARAH	1959	SEP	18	14	70	46 (NNW)	063/25.6
16	VERA	1959	SEP	26	15	78	97 (SSE)	056/33.2
17	VIRGINIA	1960	AUG	12	10	63*	81 (SSE)	071/46.6
18	WENDY	1960	AUG	13	11	45	174 (S)	070/29.1
19	DELLA	1960	AUG	30	16	55	169 (WNW)	027/29.9
20	NANCY	1961	SEP	16	18	65	18 (NW)	015/58.8
21	NORA	1962	AUG	3	8	35	55 (SSW)	106/31.7
22	THELMA	1962	AUG	27	14	30	31 (SSE)	077/24.1
23	SHIRLEY	1963	JUN	20	4	46	65 (N)	073/21.7
24	KATHY	1964	AUG	25	15	40	117 (SSE)	074/30.3
25	WILDA	1964	SEP	25	24	44	99 (SE)	049/57.1
26	JEAN	1965	AUG	6	16	60	155 (WNW)	013/40.0
27	SHIRLEY	1965	SEP	10	24	60*	60 (WNW)	031/34.2
28	TRIX	1965	SEP	18	25	62*	68 (ESE)	030/42.3
29	IDA	1966	SEP	25	23	50	134 (SSE)	049/45.5
30	DINAH	1967	OCT	28	30	49	146 (SE)	047/28.3
31	WILDA	1970	AUG	15	8	46	68 (WNW)	029/38.5
32	ANITA	1970	AUG	22	9	45	151 (WNW)	031/24.5
33	HELEN	1972	SEP	19	20	25	27 (NNW)	065/ 4.9
34	RITA	1975	AUG	23	8	30	94 (SE)	045/28.7
35	OWEN	1979	OCT	1	19	35	130 (SSE)	036/47.0
36	TIP	1979	OCT	19	23	53	163 (SE)	043/73.6
37	THAD	1981	AUG	23	15	50	8 (NNE)	005/46.3
38	JUDY	1982	SEP	12	19	40	148 (SSW)	034/36.3
39	RUBY	1985	AUG	31	14	45	177 (SSE)	042/19.9
40	ROGER	1989	AUG	28	20	40	13 (SE)	024/22.3
41	WINONA	1990	AUG	10	12	45	155 (SE)	039/26.3
42	ZOLA	1990	AUG	23	14	45	19 (ESE)	071/34.7
43	FLO	1990	SEP	20	20	53	143 (SSE)	062/35.2
44	PAGE	1990	DEC	1	29	45	145 (S)	010/24.2
45	MIREILLE	1991	SEP	27	21	63*	38 (SE)	048/58.5
46	JANIS	1992	AUG	9	11	35	34 (ESE)	039/34.0

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 41.8°N, 140.7°E.

Tropical cyclones are nurtured by a warm marine environment. In this basin maximum storm intensity typically occurs between 20°N and 25°N where sea-surface temperatures

average near 84°F (29°C) during the month of August. However, after recurvature under the influence of the mid-latitude westerlies and a colder environment, tropical cyclones lose their tropical characteristics. In this situation, the size of the circulation usually expands, the speed of the maximum wind decreases, the translational (forward) speed of motion increases and the distribution of winds, rainfall and temperature becomes increasingly asymmetric.

The primary tropical cyclone season for Hakodate extends from early August through late September. As shown in Table V-43, tropical storms have passed within 180 nmi of Hakodate as early as June, and as late as December. There were no occurrences recorded during the five-month period of January through May, and during November. It can be seen in the table that few typhoon-strength storms penetrate the 180 nmi threat radius around Hakodate. Only 4 of the 46 storms occurring during the 48-year period of record have been of typhoon strength when at their closest point of approach (CPA) to Hakodate. All four occurred during the last half of September.

Table V-43. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	0	1	1	19	20	4	0	1	46
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	0	0	4	0	0	0	4
Number of storms less than typhoon intensity at CPA	0	0	0	0	0	1	1	19	16	4	0	1	42
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	—	*	*	044	038	*	—	*	041
Average storm speed (knots) at CPA	—	—	—	—	—	*	*	30	38	*	—	*	35
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

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Table V-43 also shows the motion history of the 46 tropical storms and typhoons which passed within 180 nmi of Hakodate during the period 1945-1992. The average storm speed at CPA to Hakodate is 35 kt. The reason for this relatively rapid speed of movement is because of in the location of Hakodate. As shown in Appendix A, most tropical cyclones that pass close to Hakodate have already recurved and are moving northeastward under the influence of upper level westerlies. Since most storms accelerate after recurvature, the storms affecting Hakodate are in the acceleration phase, and rapid movement is common. The average movement for all storms is 041°/35 kt. Storms occurring during September have an average movement speed of 38 kt at CPA. As shown in Table V-42, it is not uncommon for late season storms (September and October) to exceed 50 kt.

During the 48-year period from 1945 through 1992 there were 46 tropical storms and typhoons that met the 180 nmi threat criterion for Hakodate. Figure V-174 shows the monthly distribution of the 46 storms by 7-day periods. The figure clearly shows that the period of peak activity extends from early August through late September.

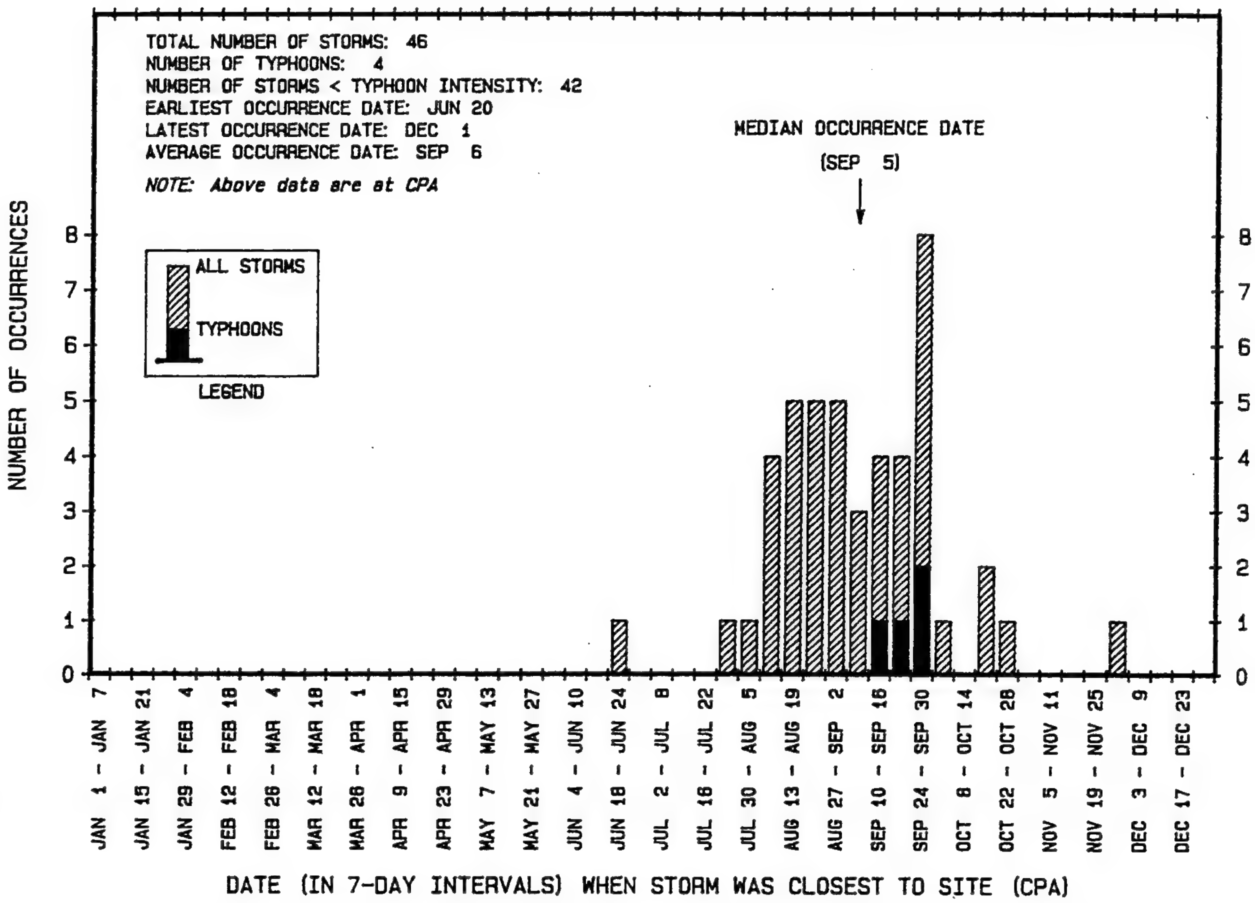

Figure V-174. Monthly distribution of the 46 tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992. The designation as a tropical storm or typhoon is based on the intensity of the storm at the time of CPA to Hakodate.

Figure V-175 depicts the annual distribution of tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992. Although the occurrence of 46 storms in 48 years suggests an average of nearly one storm per year passing within 180 nmi of Hakodate, there were many years when this event did not occur and likewise many years when there were multiple occurrences. For example, the figure shows that 30 tropical cyclones entered the 180 nmi threat radius around Hakodate during the 19-year period 1949 through 1967, an average

of approximately 1.6 per year. Only one year during the 19-year period had no storm activity recorded. However, the 21-year period 1968 through 1988 had only 9 storms enter the 180 nmi threat radius, an average of only 0.4 per year. No tropical cyclone entered the 180 nmi threat radius of Hakodate during two-thirds (14 of 21) of the years in the latter period.

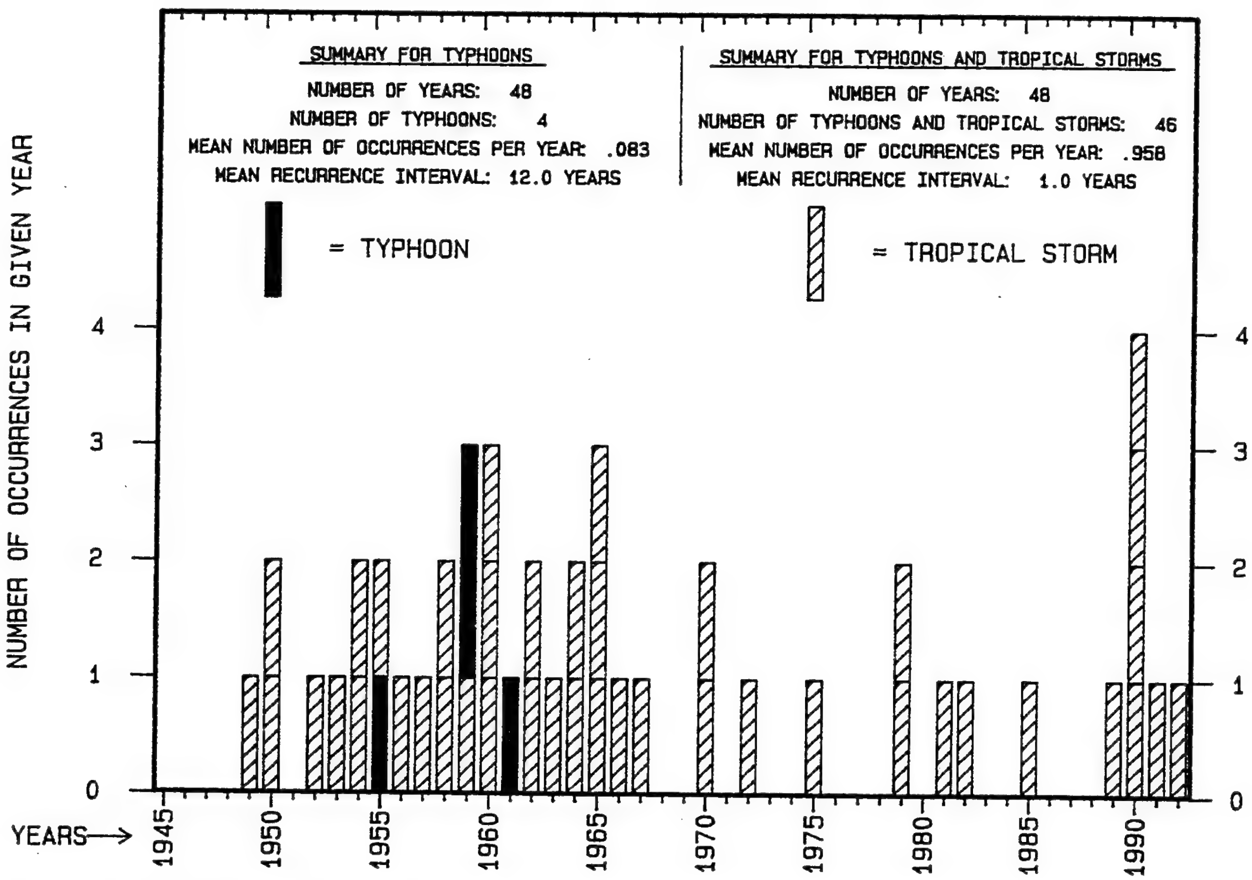

Figure V-175. Chronology of all tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992.

Figure V-176 depicts, on an 8-point compass, the octants from which the 46 tropical cyclones in the data set approached Hakodate. Sixty-one percent (28 of 46) of the storms approached Hakodate from the southwest octant, with the remainder evenly split between the west and south octants. The approach direction is determined at CPA, and may not represent the initial approach direction of the tropical cyclone toward Hakodate.

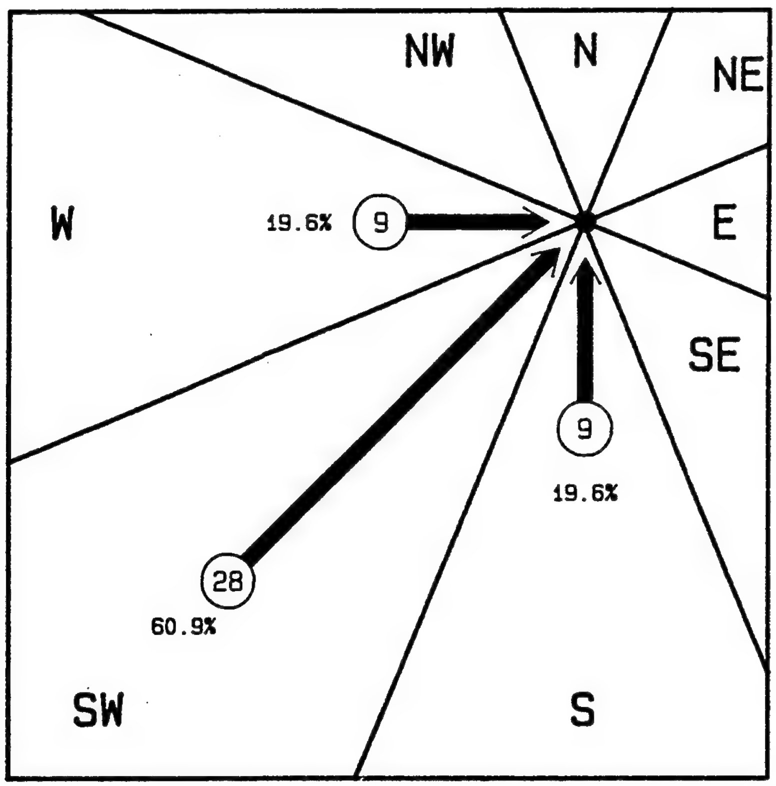

Figure V-176. Directions of approach for 46 tropical storms and typhoons passing within 180 nmi of Hakodate during the 48-year period 1945-1992. The length of each arrow is proportional to the number of storms from that direction.

Because of climatological considerations, there are preferred areas of the western North Pacific basin from which tropical cyclones eventually affect Hakodate. However, there are some tropical cyclones, which, even though they traverse these preferred areas, do not affect Hakodate. Also, as might be expected, there are seasonal shifts to these preferred areas.

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Figures V-177 and V-178 address the probability of tropical cyclones affecting Hakodate. Using a grid system, a tabulation was made of the total number of tropical cyclones passing through a given grid area regardless of whether they eventually passed within 180 nmi of Hakodate. A further tabulation was made of those storms which did eventually pass within that distance from Hakodate. After smoothing, the two tabulations were converted into probabilities and contours were drawn to connect points of equal probability.

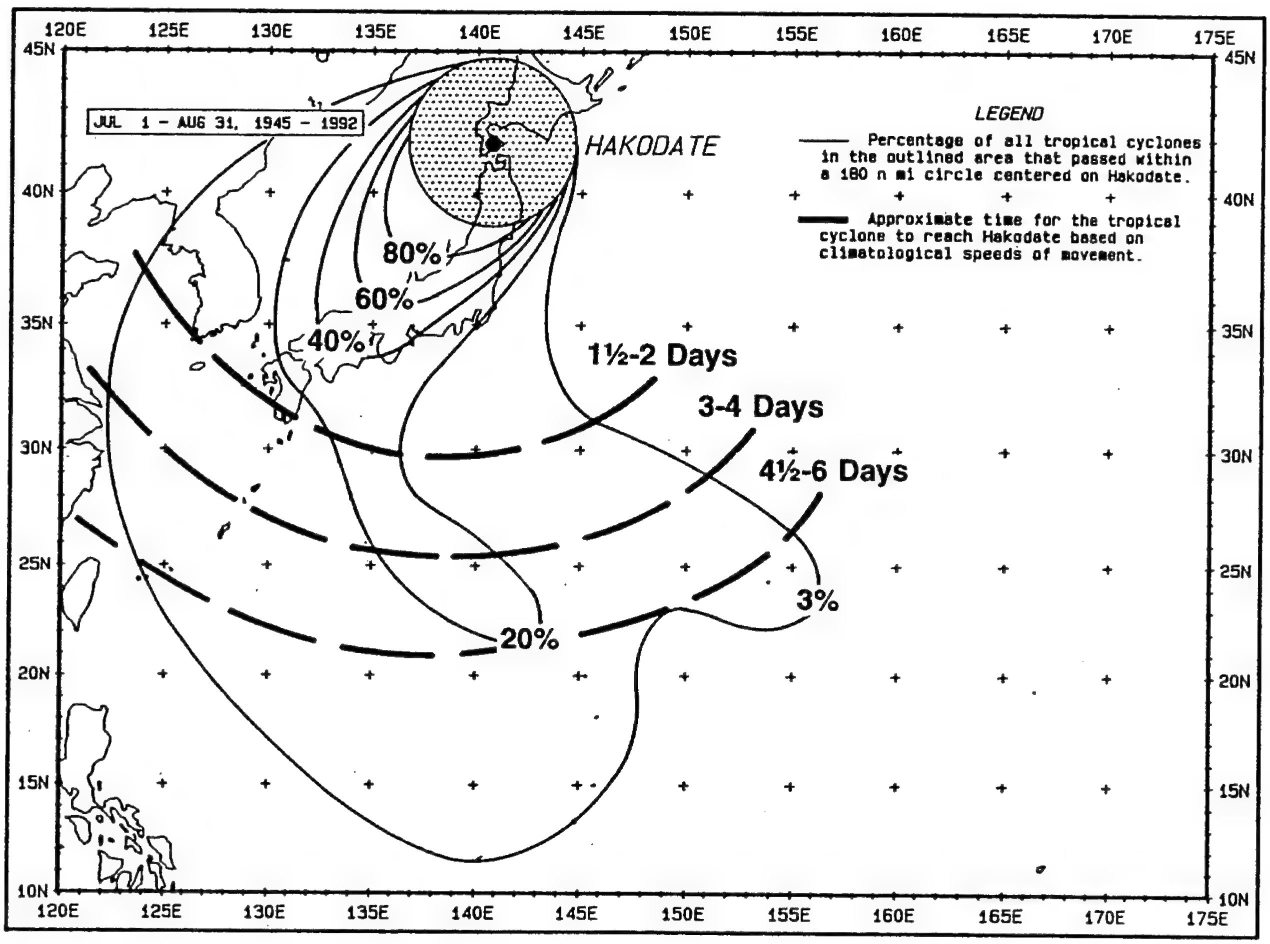

Figure V-177. Probability that a tropical storm or typhoon will pass within 180 nmi of Hakodate (circle), and approximate time to closest point of approach, during July and August.

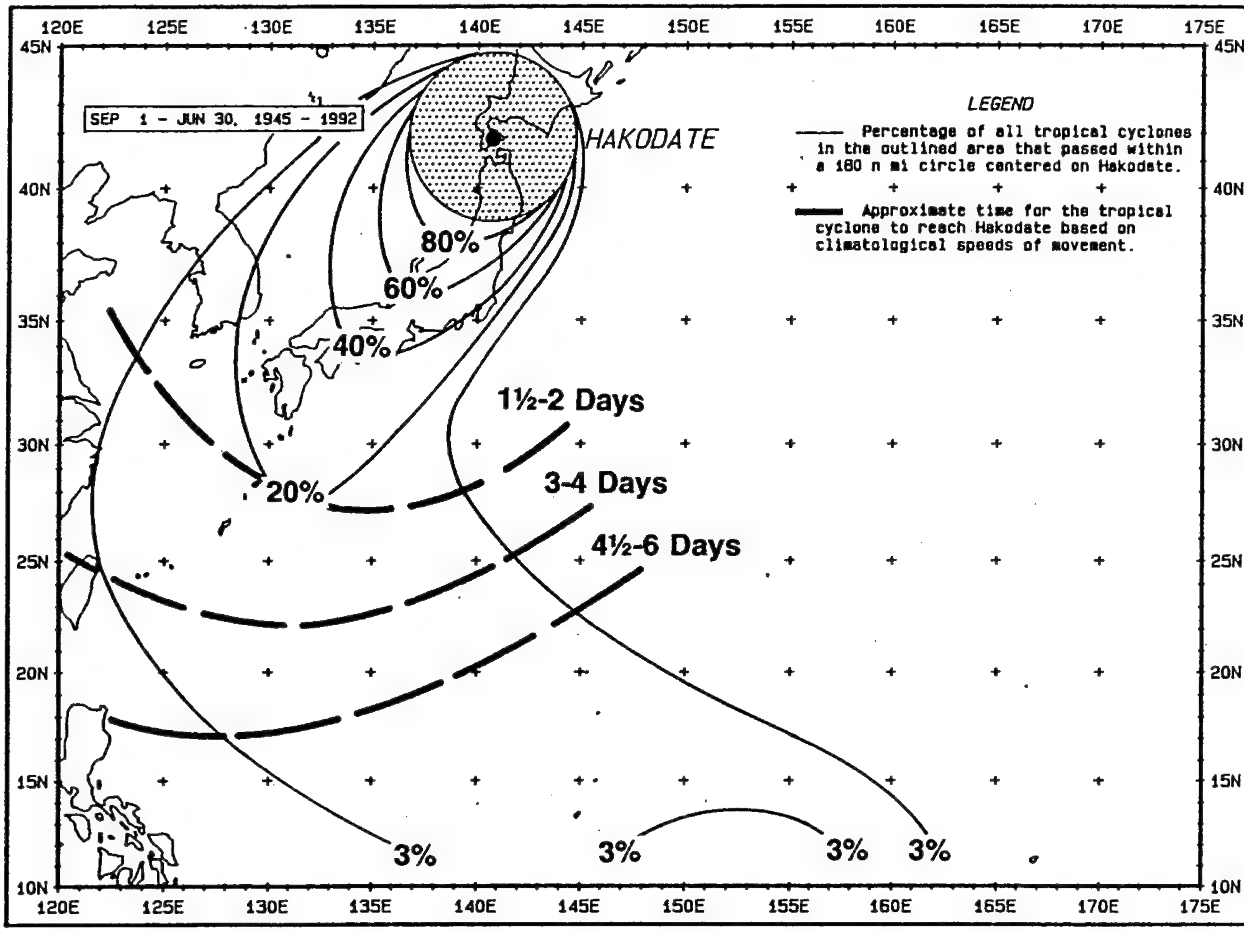

Figure V-178. Probability that a tropical storm or typhoon will pass within 180 nmi of Hakodate (circle), and approximate time to closest point of approach, during the period September through June.

The solid lines on the figures represent a "percent threat" for any tropical cyclone location within the depicted area. The heavy, dashed lines represent the approximate time in days for a system to reach Hakodate. For example, in Figure V-177, during the months of July and August a tropical cyclone located at 30°N 135°E has an approximate 25% probability of passing within 180 nmi of Hakodate and would reach Hakodate in about 1-1/2 to 2 days.

A comparison of Figures V-177 and V-178 shows that the threat axes for different times of the year are similar north of 35°N. South of 35°N, the July and August axis is broader, and the maximum threat axis is farther east than the one for the September through June period. Because of Hakodate's northerly location, essentially all of the storms that enter its 180 nmi threat radius have recurved and their movement is being influenced by upper level westerly winds. Consequently, they are moving in a general north to northeasterly direction. To pass within 180 nmi of Hakodate, the majority of the storms cross southern Honshu between 131°E and 140°E and approach Hakodate through the eastern Sea of Japan. A few pass through the Tsushima (Korea) Strait or across Korea before entering the Sea of Japan. North of 35°N, some travel northward over land, paralleling the Japanese Alps along the length of Honshu.

13.5.2 Wind and Topographical Effects

The wind observation site for the Port of Hakodate is located on a mast atop the Maritime Safety Administration building on Central Wharf (Figure V-172). The building is eight stories high. The mast on which the anemometer is located is approximately 8 ft tall and located on top of the building. Consequently, the anemometer is estimated to be between 85 and 95 ft above the water level of the harbor. Winds measured by the anemometer are considered by local authorities to be representative of harbor winds except in easterly wind situations. When easterly winds are observed, the authorities state that the Inner Harbor anchorage areas experience winds about 3 to 5 kt higher than the anemometer indicates, and the Outer Harbor anchorages experience winds about 6 to 10 kt higher. The differences in velocity are believed to be caused by the turbulence and blocking effects of the many buildings located adjacent to the east side of the harbor. The effects of the

buildings on easterly winds would decrease with increased westward distance from the buildings. Consequently when easterly winds prevail, the anchorages would experience stronger wind velocities than the east side of the inner harbor, and the westernmost anchorages would experience the strongest winds.

13.5.3 Local Weather Conditions

Observational data are available for the Hakodate area only for the period 1965 through 1992. Two observation sites recorded wind data, and neither is located at the harbor. One site is located in the city of Hakodate approximately 1.9 nmi northeast of the north part of Hakodate's Inner Harbor and at an elevation of 118 ft (36 m). The exposure of the anemometer is not known. A second observation site is located at Hakodate Airport, approximately 4.5 nmi east of the east side of the Inner Harbor near the north coast of Tsugaru Strait. The exact elevation of the airport observation site is not known, but it appears to be low lying due to its close proximity to the coast. Data from the airport site is available for the period 1975-1992 only. Observational data from each site during the passage of selected tropical cyclones are listed in Table V-44. The data contained in Table V-44 have been selected from observations recorded at Hakodate during the passage of the tropical cyclones listed in the table.[1]

An examination of the data in Table V-44 shows that there is an apparent, significant difference in the exposure of the two observation sites to wind. Two tropical cyclone passages listed in the tables occurred during the period when observations were available from both sites. The first, Thad in August 1981, caused east-southeasterly winds of 26 kt at the city site, while

[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

the airport site recorded easterly winds of 38 kt with gusts to 59 kt. The second passage, Mirielle in September 1991, brought southwesterly winds of 23 kt to the city site, but the airport site recorded southwesterly winds of 40 kt with gusts to 67 kt.

Table V-44. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Hakodate during the period 1965-1992. Direction and CPA data are in relation to approximate center position of Hakodate Harbor. Reported weather is most severe reported during entire passage of storm and did not necessarily occur coincident with strongest winds.

TROPICAL CYCLONE DATA				MOST SEVERE LOCAL CONDITIONS	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND AND GUSTS (KT)	OBSERVATION SITE AND REPORTED WEATHER
09/10/65 (SHIRLEY)	031/34	296/60	60	ESE 31	CITY SITE. MODERATE RAIN
08/15/70 (WILDA)	029/38	289/68	46	SW 29	CITY SITE. LT RAIN SHOWERS
10/19/79 (TIP)	043/74	139/163	53	NNE 28G43	AIRPORT SITE. MDT/HVY RAIN SHOWERS
08/23/81 (THAD)	005/46	026/8	50	ESE 26	CITY SITE. HEAVY/MDT RAIN SHOWERS
08/23/81 (THAD)	005/46	026/8	50	E 38G59	AIRPORT SITE. THUNDER WITH MDT/HVY RAIN
08/27/89 (ROGER)	024/22	143/13	40	E 26G37	AIRPORT SITE. VIOLENT RAIN SHOWERS
08/22/90 (ZOLA)	071/35	107/19	45	SW 20G35	AIRPORT SITE. LT/MDT RAIN SHOWERS
09/27/91 (MIRIELLE	048/58	133/38	63	SW 23	CITY SITE. LT/MDT RAIN SHOWERS
09/27/91 (MIRIELLE	048/58	133/38	63	SW 40G67	AIRPORT SITE. LT/MDT RAIN SHOWERS

Figures V-179 and V-180 show tracks and track segments of tropical cyclones considered to have a high probability of

having produced sustained winds of ≥22 kt and ≥34 kt <u>over water</u> near Hakodate during the 49-year period 1945-1993.

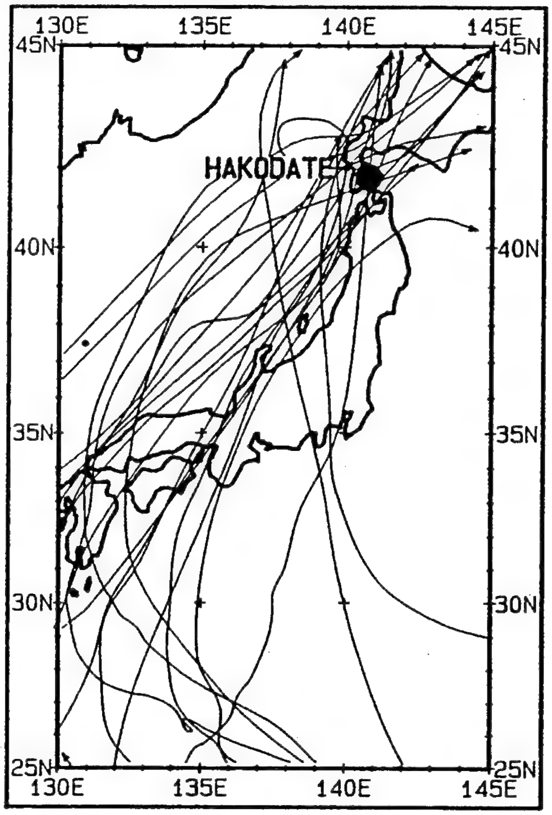

Figure V-179A.

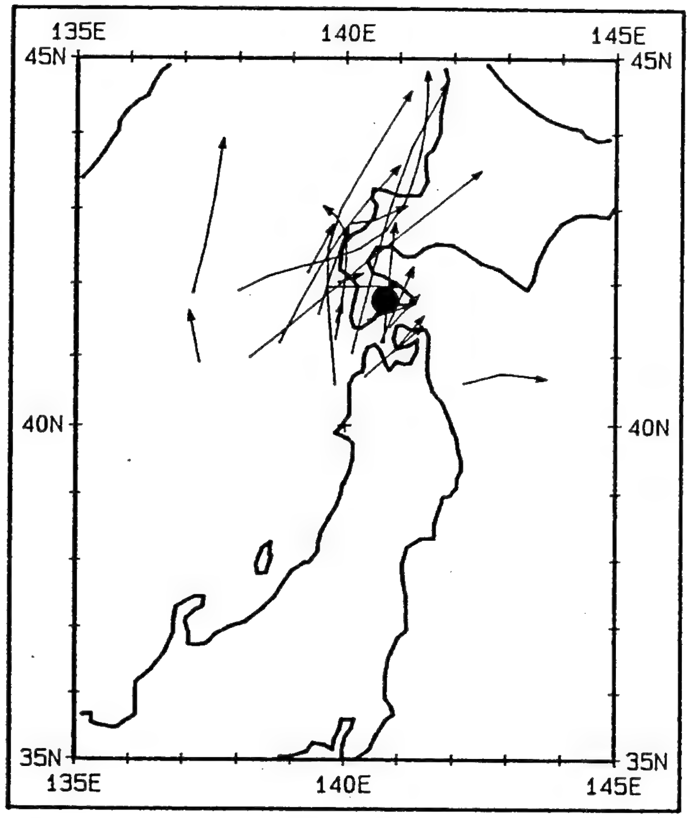

Figure V-179B.

Figure V-179. Tropical cyclones with a high probability of having produced sustained winds ≥22 kt at Hakodate during the 49-year period 1945-1993. Figure V-179A shows tracks of the 20 high probability tropical cyclones, while Figure V-179B shows track segments of the same storms when ≥22 kt winds were most likely to have occurred at Hakodate. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

It should be noted that the two figures are derived from theoretical calculations because of the limited

observational data that are available. The figures are based on: (1) storm intensity (maximum wind near center), (2) distance of the storm center from Hakodate, (3) bearing of the storm from Hakodate, (4) translational speed of the storm, and (5) frictional characteristics of the terrain between the storm and Hakodate.

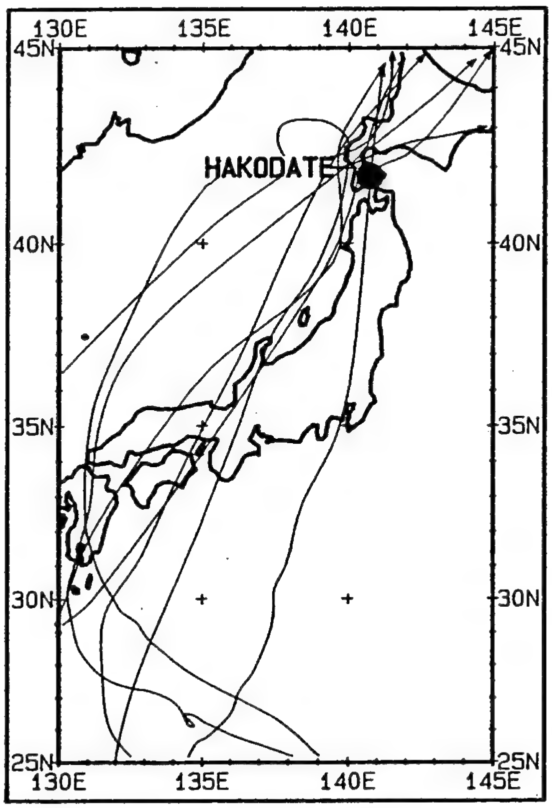

Figure V-180A.

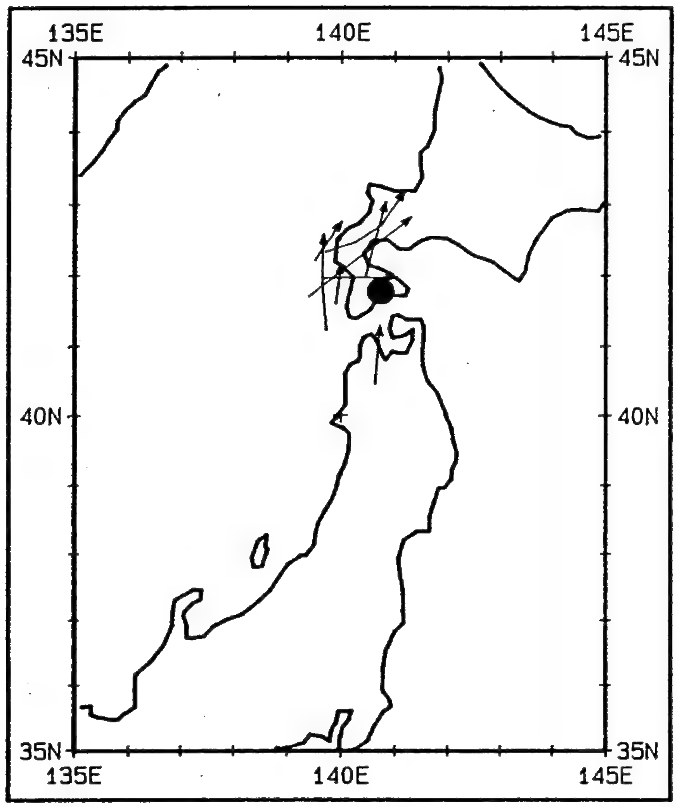

Figure V-180B.

Figure V-180. Tropical cyclones with a high probability of having produced sustained winds ≥34 kt at Hakodate during the 49-year period 1945-1993. Figure V-180A shows tracks of the 8 high probability tropical cyclones, while Figure V-180B shows track segments of the same storms when ≥34 kt winds were most likely to have occurred at Hakodate. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

The beginning and end points of the arrows in the right panel of each figure show the positions of the tropical cyclone centers when sustained winds ≥22 kt and ≥34 kt would, theoretically, have begun and ended at Hakodate.

13.5.4 Wave Motion

The Outer Harbor is exposed and vulnerable to wave motion when winds from southeast through southwest are experienced. Specific wave heights experienced at the port were not identified by local harbor authorities, but the Outer Harbor would essentially experience the same open ocean wave heights predominating in Tsugaru Strait. Consequently, combined (wind wave plus swell) wave heights of 6.5 to 10 ft (2 to 3 m) or higher could be experienced by ships in the outer anchorage, especially when southwesterly winds prevail. Local harbor authorities indicate that maximum wave height in the Inner Harbor is limited to about 3.3 ft (1 m).

The size and orientation of Hakodate Bay limits fetch and precludes large wind waves from generating and reaching the port when winds are from west clockwise through east.

13.5.5 Storm Surge

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

Local harbor authorities state that increased water levels due to storm surge have not been a significant problem in the past. Local records obtained during a 1993 port visit indicate that the maximum storm surge height experienced in recent years occurred in August 1981 when tropical cyclone Thad passed within 8 nmi of the port. A water rise of 2.4 ft (72 cm) was recorded for that storm. Other rises of 1.15 to 1.54 ft (35 to 47 cm) have been recorded since that occurrence, but some were due to extratropical low pressure systems rather than tropical cyclones. Tsugaru Strait is configured so that the only wind flow that would likely cause damaging storm surge at Hakodate would be from south clockwise through southwest. A strong, slow moving storm passing just west of Hakodate could potentially cause a storm surge at the port. However, the generally rapid movement of most tropical cyclones as they approach Hakodate would likely prevent the sustained wind flow necessary to cause a significant storm surge.

13.6 THE DECISION TO EVADE OR REMAIN IN PORT

13.6.1 General

The lack of protection from wind within the Port of Hakodate precludes any decision to remain in the Inner Harbor during the passage of a tropical cyclone. The exposure of ships to wind and waves in the anchorage west of the breakwaters makes

remaining at anchor inadvisable. In a tropical cyclone threat situation local port authorities strongly recommend that all large ships leave the port. During a 1993 port visit, port authorities at Otaru mentioned that a large ferry was sunk at Hakodate during the passage of a typhoon "about 40 years ago" but they did not have specific information about the event. Hakodate harbor authorities could not provide additional information. Harbor congestion is a problem at Hakodate when the port is threatened by high winds. However, when the port is threatened by a tropical cyclone most fishing vessels and other small craft choose to go to Mutsu Bay (Figure V-170) on the north end of Honshu.

13.6.2 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when his/her ship is exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/JTWC) Guam tropical cyclone warnings, and a basic understanding of weather will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures V-177 and V-178, discussed earlier, addressed the probability of existing remotely located tropical cyclones later affecting Hakodate. Figures V-181 and V-182 have been prepared as additonal aids for the commander to use when evaluating a given situation. In contrast to Figures V-177 and V-178, Figures V-181 and V-182 consider only those storms which later passed within 180 nmi of Hakodate. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered

as an <u>average</u> approach scenario insofar as Hakodate is concerned. It must be stressed that the other 50% of the storms which later affect Hakodate will be <u>outside</u> of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures V-181 and V-182.

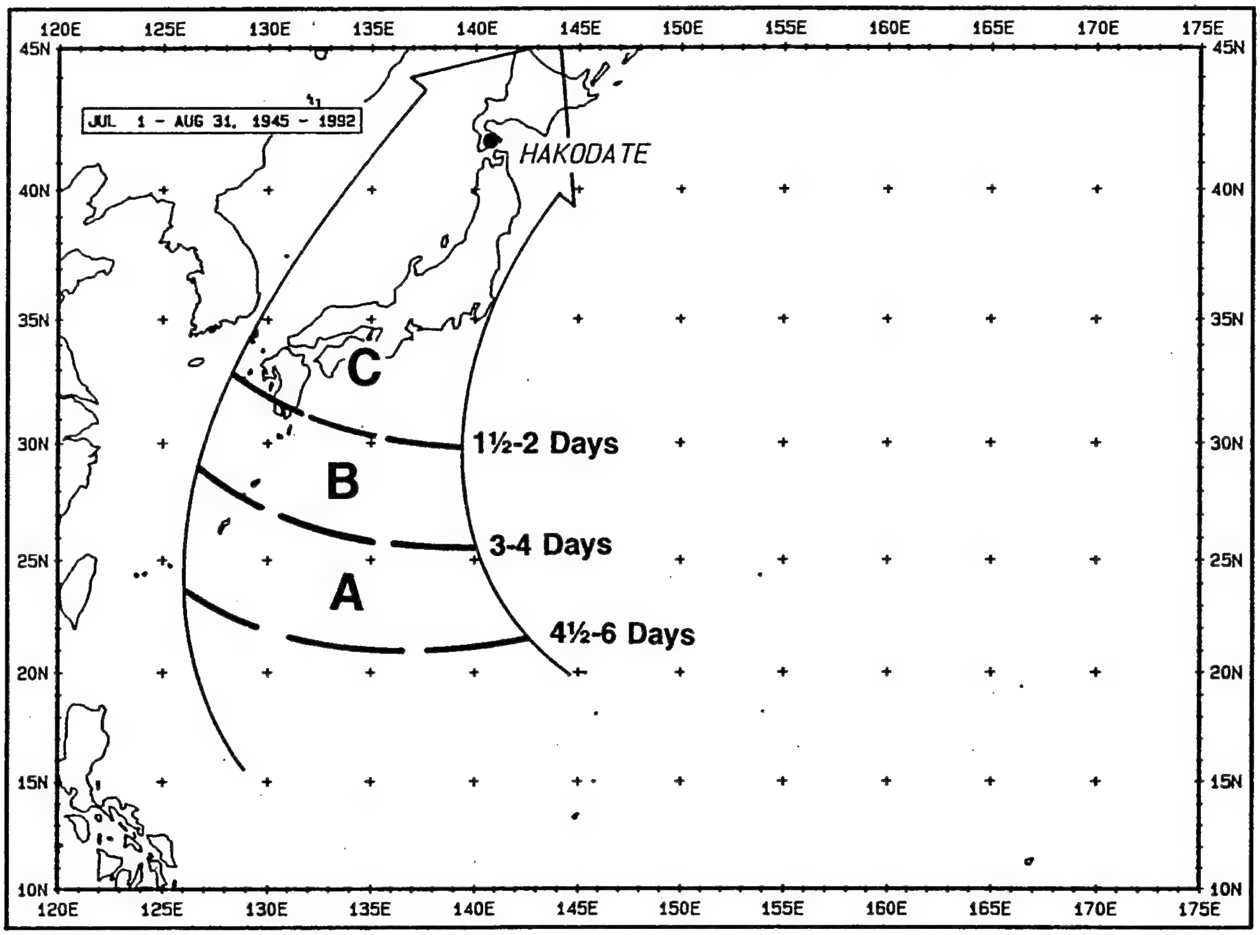

Figure V-181. For the tropical cyclones passing within 180 nmi of Hakodate during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 mi of Hakodate. See Figure V-177 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Hakodate.

HAKODATE

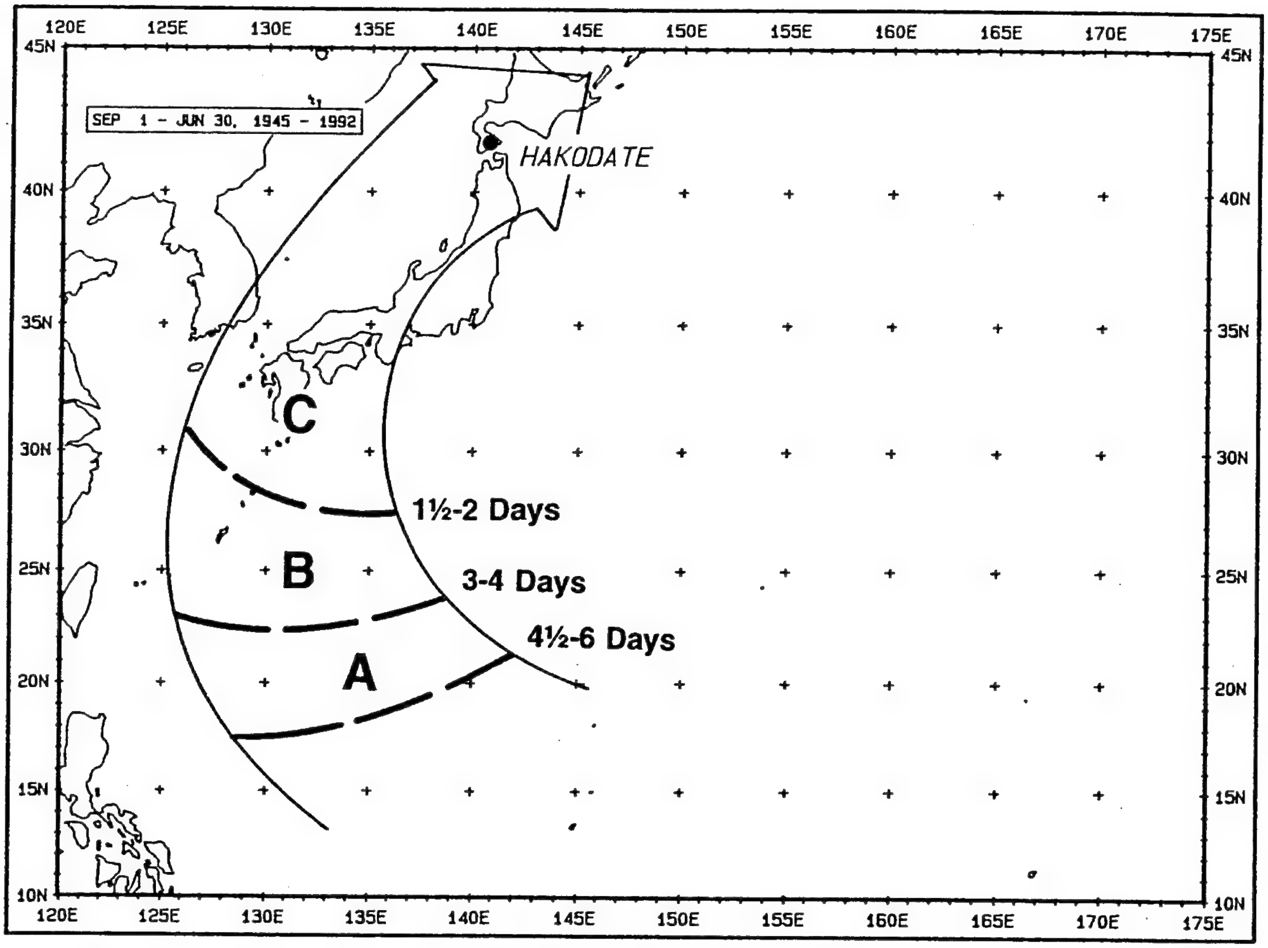

Figure V-182. For the tropical cyclones passing within 180 nmi of Hakodate during the period September through June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 mi of Hakodate. See Figure V-178 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Hakodate.

With the above restrictions in mind, the following time/action sequence aids, to be used in conjunction with Figures V-181 and V-182, are provided.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast toward Hakodate:

a. Review material condition of ship.

b. Formulate plans for expeditious sortie from the harbor and evasion route to be taken in the event the tropical cyclone threatens Hakodate.

c. Reconsider any maintenance that would render the ship incapable of getting under way, if need be, within 48 hours.

d. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Hakodate (recall that tropical cyclones tend to accelerate rapidly after recurvature).

a. Reconsider any maintenance that would render the ship incapable of getting underway, if need be, within 24 hours.

b. Finalize plans for expeditious sortie from the harbor and evasion route to be taken in the event the tropical cyclone threatens Hakodate.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone has entered Area C and is moving toward Hakodate:

a. Sortie from the harbor, taking an evasion route that will allow the unit to encounter the most favorable weather conditions during the passage of the tropical cyclone.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

13.6.3 Evasion at Sea

Evasion routes at sea may be developed by using NPMOCW/ JTWC tropical cyclone warnings (see Chapter I), and Appendix A (Bi-Weekly Tropical Storm and Typhoon Tracks for the Western North Pacific Ocean) for the period of interest. They should be used in conjunction with Figures V-177 and V-178 (tropical cyclone threat axes and approach times to Hakodate). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

Two basic evasion routes are available: (1) moving west through Tsugaru Strait and entering the Sea of Japan, and (2) proceeding east through Tsugaru Strait into the Pacific Ocean and proceeding south along the east coast of Honshu. If the tropical cyclone is moving northeastward on a track that would take it east of Hakodate, remaining in the Sea of Japan would keep the vessel on the weaker, left side of the storm's circulation and thereby avoid the strongest winds of the storm. However, the ship may be exposed to relatively strong winds from the northwest quadrant as the storm passes and high pressure moves into the Sea of Japan behind the storm's circulation.

If the storm is forecast to pass west of Hakodate, moving eastward into the Pacific Ocean along the east coast of Honshu should be considered. It must be emphasized that this option has a potentially serious drawback. If the tropical cyclone should move east of the forecast track, and therefore closer to the ship's evasion route, the ship may encounter the strong winds of the storm's dangerous semicircle. In a best case situation, depending on the size of the storm's circulation the ship may still be liable to encounter strong southerly winds along the coast. However, the strongest winds should be short

lived because of the historically rapid movement of tropical cyclones when they reach the latitudes of northern Japan.

Regardless of the option chosen, it is of utmost importance to begin the sortie as early as possible. The average speed of movement of tropical cyclones occurring during the 48-year period 1945-1992 is 35 kt when at CPA to Hakodate (Table V-43). Those occurring during September average a relatively rapid 38 kt, so some storms will move even faster. As an example, as shown in Table V-42 tropical storm Tip was moving at over 73 kt when at CPA to Hakodate. Several others were moving at over 50 kt.

Once clear of the harbor, an evading vessel steaming at 20 kt will take approximately 2 hours to exit Tsugaru Strait into the Sea of Japan or the Pacific Ocean. To gain an additional 200 nmi clearance from the forecast storm track will take another 10 hours. During this 12-hour period, a storm moving at only 35 kt would have moved about 420 nmi closer to Hakodate.

It must be remembered that tropical cyclones are notoriously difficult to accurately forecast, especially in the recurvature phase; the 48-hour forecast position error may exceed 200 nmi. A storm may be closer to or farther from Hakodate at forecast verification time than the forecast indicates, or right or left of the storm's forecast track. Each tropical storm or typhoon must be considered as differing from those preceding it. The accompanying synoptic situation must be fully understood. To blindly establish and follow only one technique or rule for avoiding a storm's danger area is not prudent and, in fact, may ultimately place the ship in harm's way.

REFERENCES

FICPAC, 1988: Port Directory for Hakodate, Japan, Change 7. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with Mr. Nobuhiro Takemoto, Chief, Hakodate Maritime Safety Office; Mr. Taizo Kikui, Chief, Guard and Rescue Division, Hakodate Maritime Safety Office; and Mr. Akihiko Noda, Head, and Mr. Mitsuho Kururi, Head Administrator of the Administration Section, Harbor Department, Hakodate City, to obtain much of the information contained in this port evaluation.

14. OMINATO

SUMMARY

The conclusion reached in this study is that the Port of Ominato cannot be considered a safe haven for ships when it is threatened by strong wind. The reasons for the conclusion include:

(1) Ominato Harbor offers no protection from wind. Ships at the port, whether moored or anchored, are exposed to the full force of strong wind events.

(2) Tug boats are not available to aid ships that may need assistance in strong wind situations.

14.1 LOCATION

The Port of Ominato is located at approximately 41°16'N 141°10'E in the northeast corner of Mutsu (alternate spelling Mutu) Bay on the north end of Honshu, the largest of the four main islands of Japan (Figure V-183).

14.2 OMINATO HARBOR

The port is situated in the northern part of Mutsu Bay (Figure V-184). The port is named for a small community adjacent to the harbor, but the facility is generally associated with the larger, nearby community of Mutsu.

The port is divided into two main sections, Ashizaki Bay and facilities on the Tanabu River near its mouth (Figure V-185). Ashizaki Bay is used primarily by the Japanese Maritime Self Defense Force (JMSDF) and the Mutsu establishment of the Japan Atomic Energy Research Institute. There are no berthing

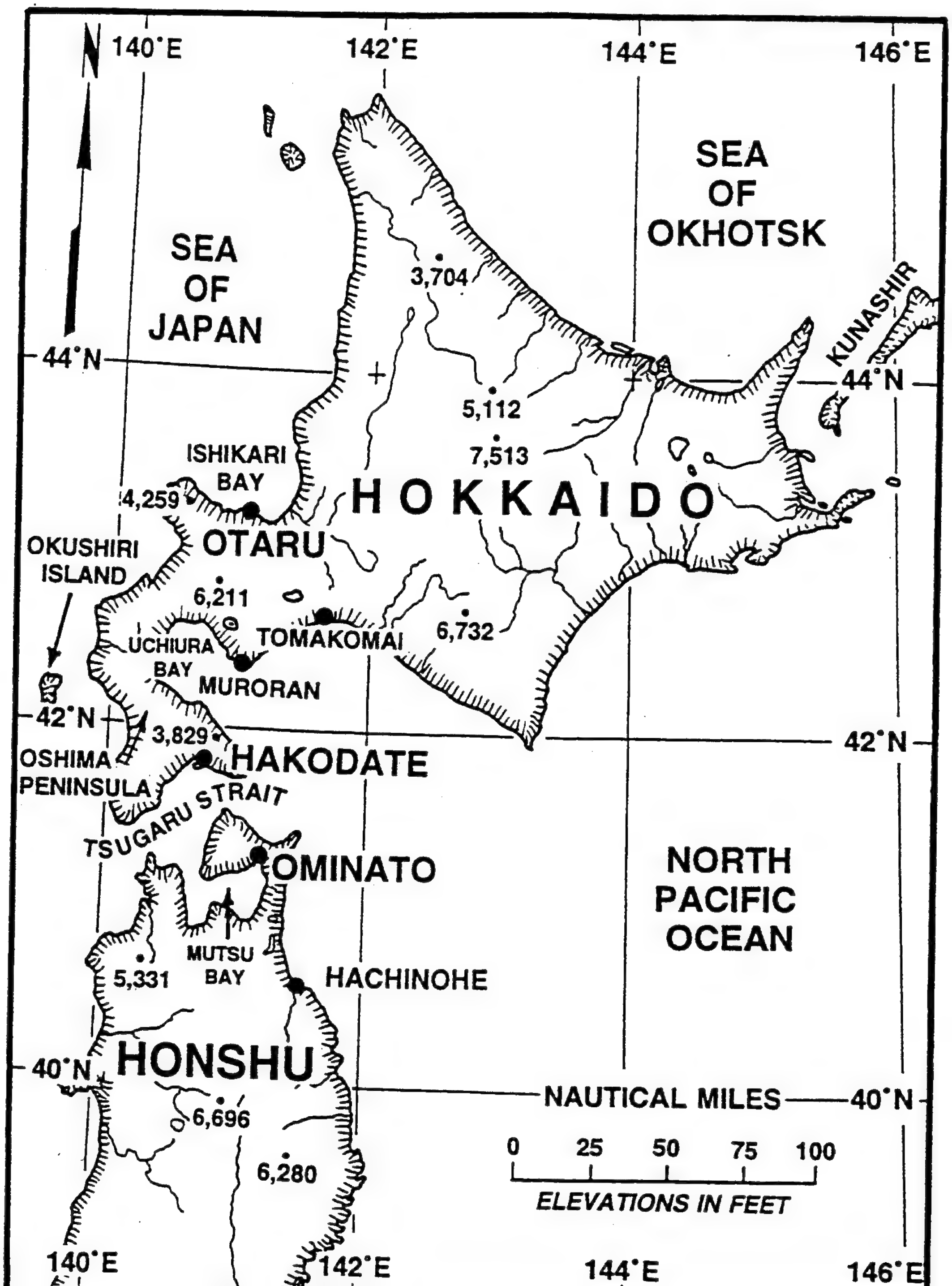

Figure V-183. Location of Ominato on Honshu and its position relative to other significant ports in northern Japan.

accommodations for U. S. Navy ships in Ashizaki Bay. Visiting U. S. Navy ships have the options of mooring to a berth in the mouth of the Tanabu River or anchoring.

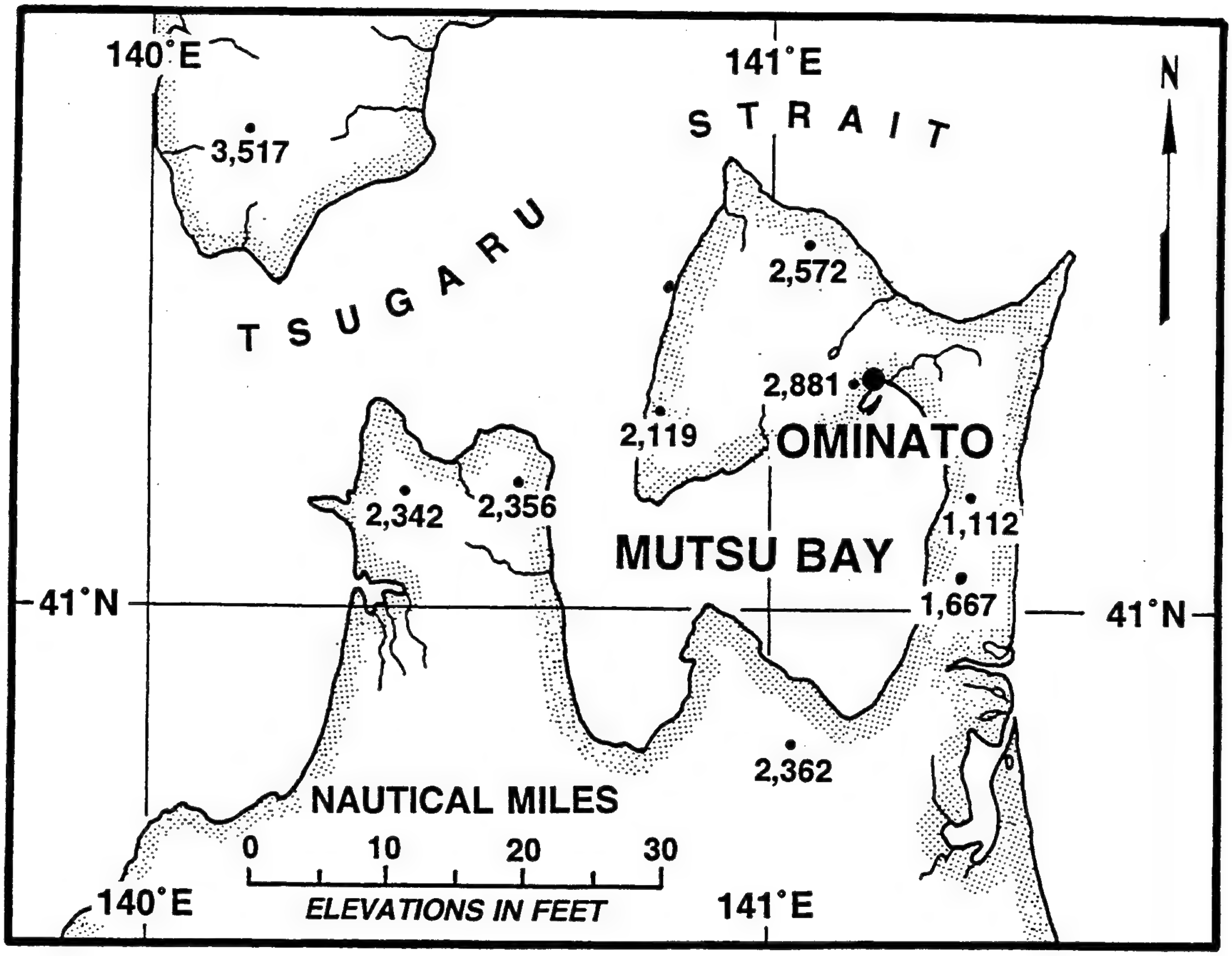

Figure V-184. Location of the Port of Ominato on Mutsu Bay.

Four berths are located near the mouth of the Tanabu River. Either of the two westernmost berths on the south side of the river may be assigned to a U. S. Navy ship. According to a Mutsu city official, U. S. Navy ships would most likely be assigned to the second berth from the river's mouth. It is approximately 690 ft (210 m) long with a minimum charted alongside depth of 21 ft (6.4 m). The berth closest to the river's mouth on its south

side is approximately 570 ft (174 m) long with a minimum charted alongside depth of 23 ft (7 m). Both of the aforementioned berths have built-in rubber fenders. It is estimated that the port can accommodate two DD/FF type ships (FICPAC, 1986).

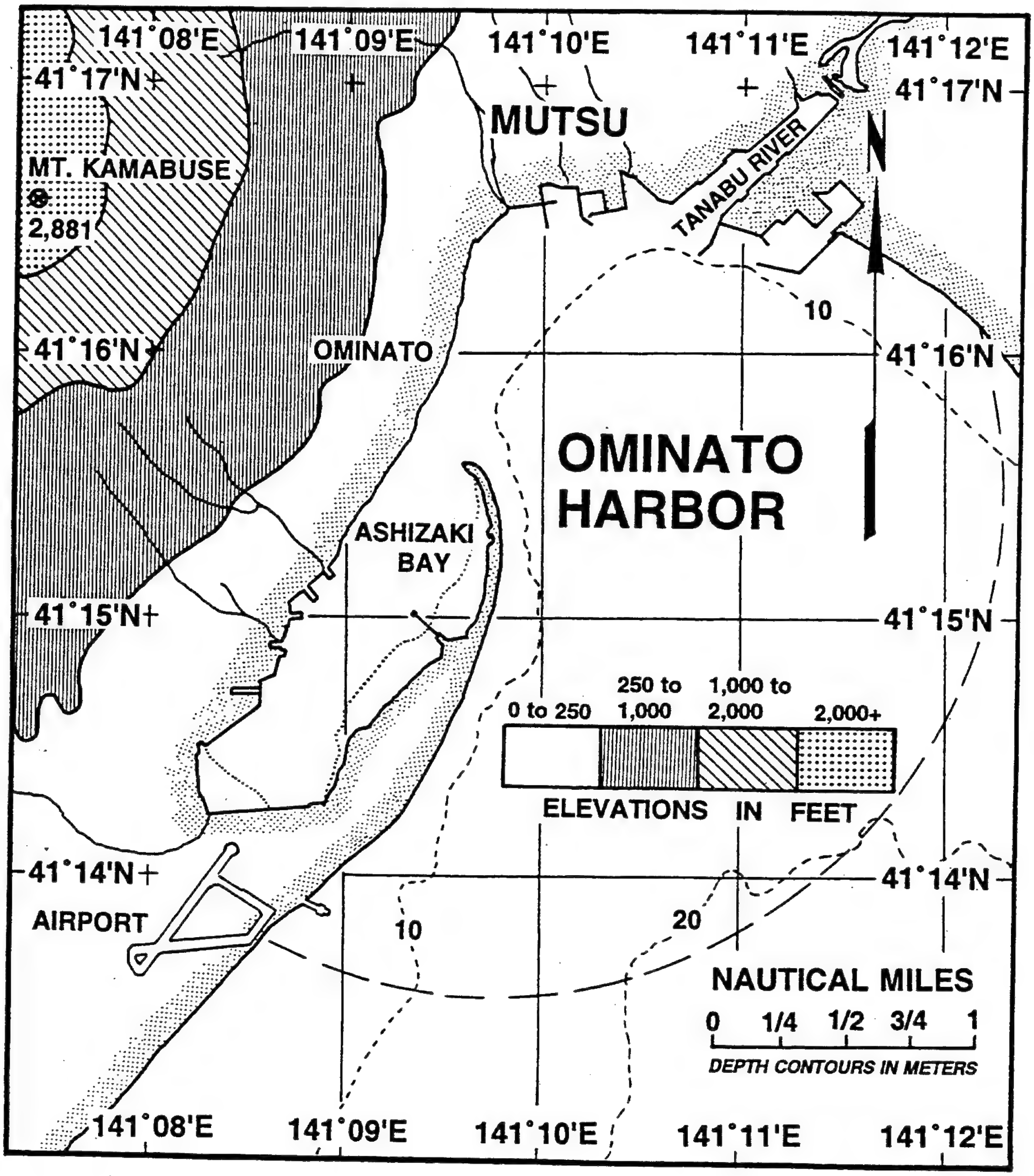

Figure V-185. Configuration of the Port of Ominato.

The two other berths located on the Tanabu River near its mouth would not likely be assigned to a U. S. Navy ship. One, a relatively short berth approximately 300 ft (91 m) long, is the third berth from the mouth of the river on its south side. The minimum charted depth adjacent to the berth is less than 19.7 ft (6 m). The other berth, approximately 850 ft (259 m) long, is located on the north side of the river about 300 yd east of the river's mouth. Charted alongside depths range from 22.3 ft (6.8 m) near its western end to 25.3 ft (7.7 m).

There is no specifically designated anchorage area. Ashizaki Bay (Figure V-185) is considered by local officials to be suitable for anchoring. A city official described the bottom as being sand. The best anchorages are in the outer bay in depths of 32.8 to 65.6 ft (10 to 20 m) (FICPAC, 1986). An Amphibious Command ship (620 ft long, 19,290 tons) anchored at 41°15'48"N 141°10'42"E in a depth of 42 ft (12.8 m), and reported excellent holding on a mud bottom.

Harbor pilots are available, but their use is not mandatory (FICPAC, 1986). The same document states that pilots could aid in the location of local fishing nets to avoid fouling. According to a Mutsu city official, the port has no tug boats.

14.3 HARBOR FACILITIES

Ominato is a small harbor with no significant repair or cargo handling facilities. During a 1986 port visit by a U. S. Navy ship, a Fleet Landing was established in Ashizaki Bay at an unspecified JMSDF pier.

14.4 TOPOGRAPHY

Kamabuse Mountain, a conical 2,881 ft (878 m) volcanic peak, dominates the local landscape (Figures V-185 and V-186). The peak of the mountain lies less than 3 nmi west of the mouth of Tanabu River. The remainder of the terrain west and northwest of Mt. Kamabuse is rugged, with many peaks exceeding 2,625 ft (800 m). With the exception of Mt. Kamabuse, the terrain immediately adjacent to the port of Ominato is mostly low-lying. Elevations northeast of the port are less than 328 ft (100 m) across the approximate 7 nmi wide strip of land that separates Mutsu Bay from the east end of Tsugaru Strait. Maximum elevations within 10 nmi east and southeast of the port are limited to less than 984 ft (300 m) except for one peak that reaches 1,112 ft (339 m).

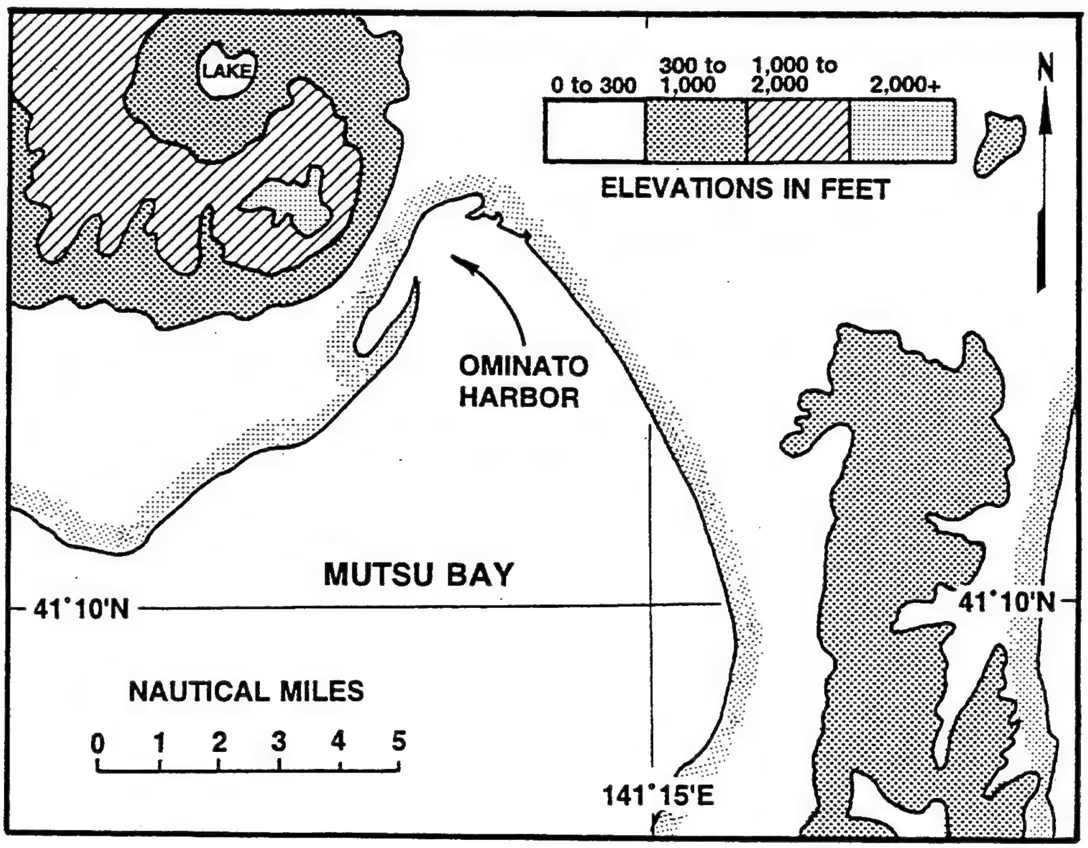

Figure V-186. Topography adjacent to the Port of Ominato.

14.5 TROPICAL CYCLONES AFFECTING OMINATO

14.5.1 Tropical Cyclone Climatology at Ominato

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Ominato is considered to represent a threat to the port. Table V-45 contains a descriptive history of all 46 tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992. Unless otherwise indicated, all of the tropical cyclone statistics used in this report are based on the data set used to compile Table V-45.

Tropical cyclones which affect Japan generally form in the area bounded by 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment.

Considering the entire western North Pacific basin, about two-thirds of the tropical cyclones reach at least typhoon intensity at some point in their life cycle. Although there is a positive correlation between the maximum storm intensity and the eventual intensity of the storm at CPA to Ominato, the relationship is very weak. Much depends on the track of the storm before it reaches Ominato.

Tropical cyclones are nurtured by a warm marine environment. In this basin maximum storm intensity typically occurs between 20°N and 25°N, where sea-surface temperatures average near 84°F (29°C) during the month of August. However, after recurvature into the westerlies and the association with a colder environment, tropical cyclones lose their tropical

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Table V-45. Descriptive history of the 46 tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	KITTY	1949	SEP	1	9	44	77 (WNW)	015/35.3
2	JANE	1950	SEP	3	8	44	17 (WNW)	040/30.3
3	KEZIA	1950	SEP	14	9	52	45 (NNW)	078/52.6
4	KAREN	1952	AUG	19	8	40	113 (N)	085/22.0
5	TESS	1953	SEP	25	15	52	77 (ESE)	031/32.5
6	KATHY	1954	SEP	8	9	38	128 (WNW)	032/41.5
7	MARIE	1954	SEP	26	12	65	64 (W)	355/38.8
8	LOUISE	1955	SEP	30	15	73	71 (NW)	051/34.1
9	OPAL	1955	OCT	20	19	38	140 (ESE)	038/53.7
10	BABS	1956	AUG	18	9	32	61 (WNW)	016/11.1
11	BESS	1957	SEP	7	9	39	23 (SSE)	059/36.9
12	ALICE	1958	JUL	23	9	52	46 (ENE)	018/38.2
13	IDA	1958	SEP	27	15	30	114 (ESE)	021/20.3
14	GEORGIA	1959	AUG	14	7	58	177 (W)	350/37.4
15	SARAH	1959	SEP	18	14	70	83 (NNW)	063/25.6
16	VERA	1959	SEP	26	15	78	60 (SSE)	056/33.2
17	VIRGINIA	1960	AUG	12	10	63*	48 (S)	071/46.6
18	WENDY	1960	AUG	13	11	45	141 (S)	070/29.1
19	NANCY	1961	SEP	16	18	65	48 (WSW)	016/58.4
20	NORA	1962	AUG	3	8	35	27 (S)	095/35.3
21	THELMA	1962	AUG	27	14	30	10 (WNW)	077/24.1
22	SHIRLEY	1963	JUN	20	4	46	100 (NNW)	073/21.7
23	KATHY	1964	AUG	25	15	40	80 (SSE)	074/30.3
24	WILDA	1964	SEP	25	24	44	61 (SE)	049/57.1
25	SHIRLEY	1965	SEP	10	24	60*	93 (NW)	031/34.2
26	TRIX	1965	SEP	18	25	63*	38 (SE)	029/42.7
27	KIT	1966	JUN	28	4	43	166 (ESE)	035/30.8
28	IDA	1966	SEP	25	23	50	97 (SSE)	049/45.5
29	DINAH	1967	OCT	28	30	49	110 (SE)	047/28.3
30	WILDA	1970	AUG	15	8	46	99 (WNW)	029/38.5
31	ANITA	1970	AUG	22	9	45	179 (WNW)	031/24.5
32	HELEN	1972	SEP	17	20	50	60 (WNW)	009/18.2
33	RITA	1975	AUG	23	8	30	59 (SE)	045/28.7
34	OWEN	1979	OCT	1	19	35	94 (SSE)	036/47.0
35	TIP	1979	OCT	19	23	53	126 (SE)	043/73.6
36	THAD	1981	AUG	23	15	52	20 (WSW)	005/43.2
37	JUDY	1982	SEP	12	19	40	129 (SW)	034/36.3
38	RUBY	1985	AUG	31	14	45	140 (SSE)	042/19.9
39	ROGER	1989	AUG	27	20	40	23 (W)	024/27.2
40	WINONA	1990	AUG	10	12	45	120 (SE)	039/26.3
41	ZOLA	1990	AUG	23	14	45	26 (N)	071/34.7
42	FLO	1990	SEP	20	20	53	106 (SSE)	062/35.2
43	PAGE	1990	DEC	1	29	45	111 (S)	010/24.2
44	HARRY	1991	AUG	31	16	40	179 (SSE)	056/33.5
45	MIREILLE	1991	SEP	27	21	63*	10 (NE)	048/58.5
46	JANIS	1992	AUG	9	11	35	17 (NE)	039/34.0

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 41.3°N, 141.1°E.

characteristics. In this situation, the size of the circulation usually expands, the speed of the maximum wind decreases, the translational (forward) speed of motion increases and the distribution of winds, rainfall and temperature becomes increasingly asymmetric.

Although tropical cyclones have occurred during all months in the genesis area described in the preceding paragraphs, the primary season for Ominato is during August and September. As shown in Table V-46, tropical storms have passed within 180 nmi of Ominato as early as June and as late as December, but none has passed during November or during the five-month period of January through May. Few typhoon-strength (≥64 kt) storms penetrate the 180 nmi threat radius around Ominato. Only 11% (5 of 46) of the total number of storms occurring during the 48-year period of record have been of typhoon strength when at their closest point of approach (CPA) to Ominato. The typhoon strength storms all occurred during September.

Table V-46. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	0	2	1	18	20	4	0	1	46
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	0	0	5	0	0	0	5
Number of storms less than typhoon intensity at CPA	0	0	0	0	0	2	1	18	15	4	0	1	41
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	—	*	*	047	038	*	—	*	042
Average storm speed (knots) at CPA	—	—	—	—	—	*	*	30	38	*	—	*	35
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

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Table V-46 also shows the motion history of the 46 tropical storms and typhoons which passed within 180 nmi of Ominato during the 48-year period 1945-1992. The table shows that the average storm speed at CPA is 35 kt. The reason for the relatively rapid movement lies in the location of Ominato. As shown in Appendix A, most tropical cyclones that pass close to Ominato have already recurved and are moving northeastward under the influence of upper level westerlies. Since such storms commonly accelerate after recurvature, many of the storms entering Ominato's 180 nmi threat radius are in the acceleration phase, and rapid movement is common. While the average movement for all storms at CPA to Ominato is 042°/35 kt, storms occurring during September have a 38 kt average speed. As shown in Table V-45, it is not uncommon for September and October storms to exceed 50 kt. The fastest, tropical storm Tip in October 1979, was moving at a speed of over 73 kt when at CPA to Ominato.

During the 48-year period from 1945 through 1992 there were 46 tropical storms and typhoons that met the 180 nmi threat criterion for Ominato. Figure V-187 shows the monthly distribution of the 46 storms by 7-day periods. The period of peak activity extends from early August through late September.

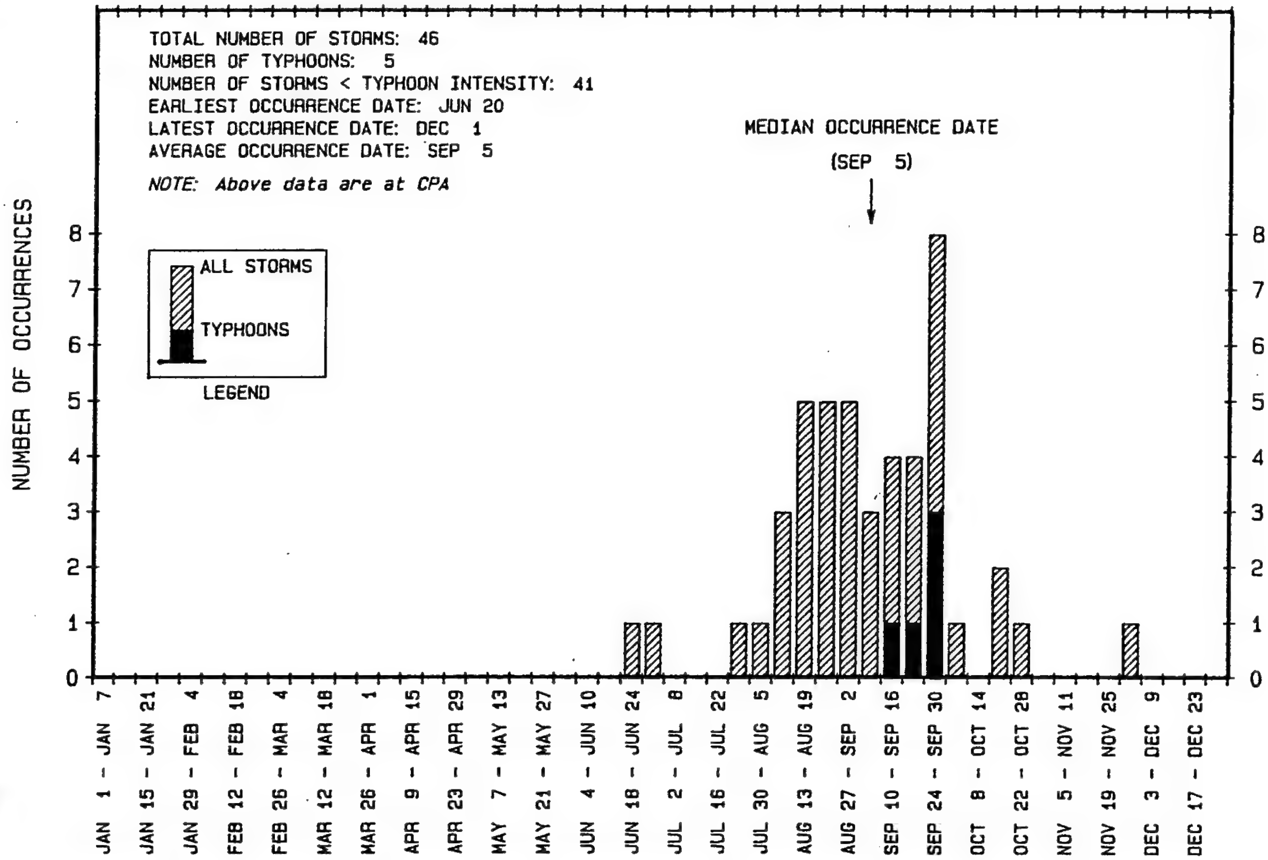

Figure V-187. Monthly distribution of the 46 tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992.

Figure V-188 depicts the annual distribution of tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992. Although the occurrence of 46 storms in 48 years suggests an average of nearly one storm per year passing within 180 nmi of Ominato, there were many years when this event did not occur and, likewise, many years when there were multiple occurrences. For example, the figure shows that 29 tropical cyclones entered the 180 nmi threat radius around Ominato during the 19-year period 1949 through 1967, an average of approximately 1.5 per year. Only one year during the

19-year period had no storm activity recorded. However, the 21-year period 1968 through 1988 had only 9 storms enter the 180 nmi threat radius, an average of only 0.4 per year. No tropical cyclone entered the 180 nmi threat radius of Ominato during two-thirds (14 of 21) of the years in the latter period.

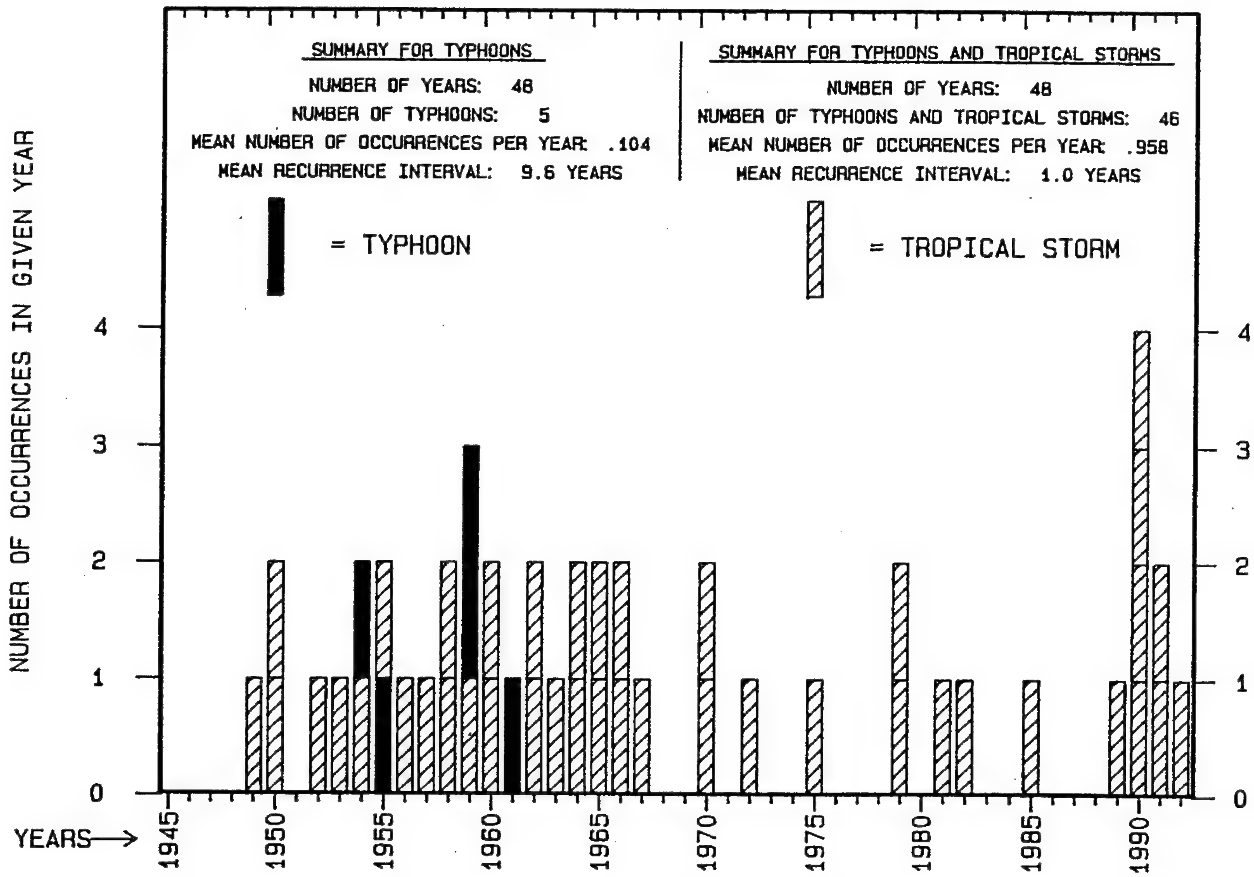

Figure V-188. Chronology of all tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992. The designation as a tropical storm or typhoon is based on the intensity of the storm at the time of CPA to Ominato.

Figure V-189 depicts, on an 8-point compass, the octants from which the 46 tropical cyclones in the data set approached Ominato. Fifty-nine percent (27 of 46) of the storms approached Ominato from the southwest octant, with the remainder almost evenly split between the west and south octants. It

should be noted that the approach direction is determined at CPA, and may not represent the initial approach direction of the tropical cyclone toward Ominato.

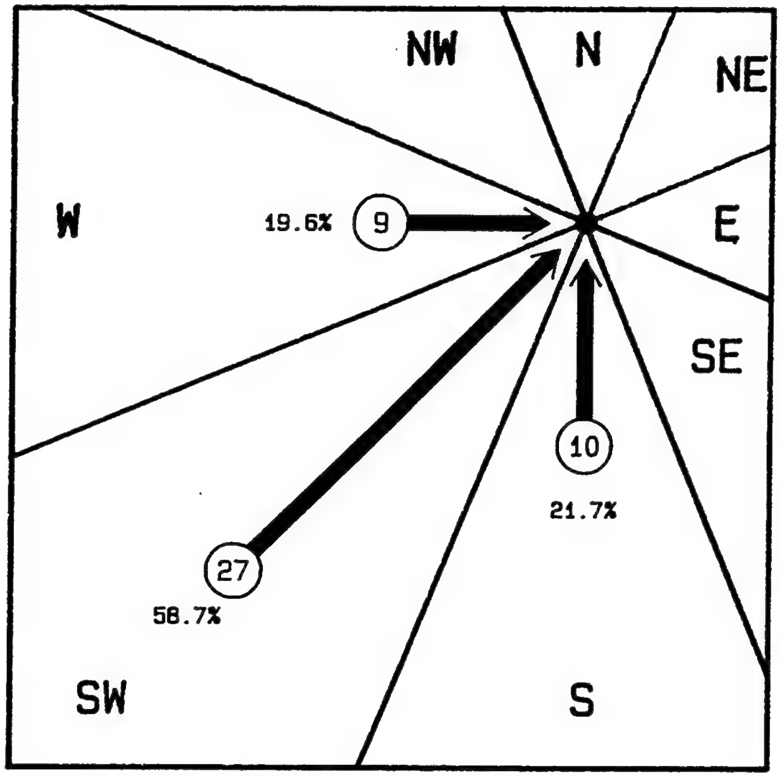

Figure V-189. Directions of approach for 46 tropical storms and typhoons passing within 180 nmi of Ominato during the 48-year period 1945-1992. The length of each arrow is proportional to the number of storms from that direction.

Because of climatological considerations, there are preferred areas of the western North Pacific basin from which tropical cyclones eventually affect Ominato. However, there are some tropical cyclones, which, even through they traverse these preferred areas, do <u>not</u> affect Ominato. Also, as might be expected, there are seasonal shifts to these preferred areas.

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Figures V-190 and V-191 address the probability of tropical cyclones affecting Ominato. Using a grid system, a tabulation was made of the total number of tropical cyclones passing through a given grid area regardless of whether they eventually passed within 180 nmi of Ominato. A further tabulation was made of those storms which did eventually pass within that distance from Ominato. After smoothing, the two tabulations were converted into probabilities and contours were drawn to connect points of equal probability.

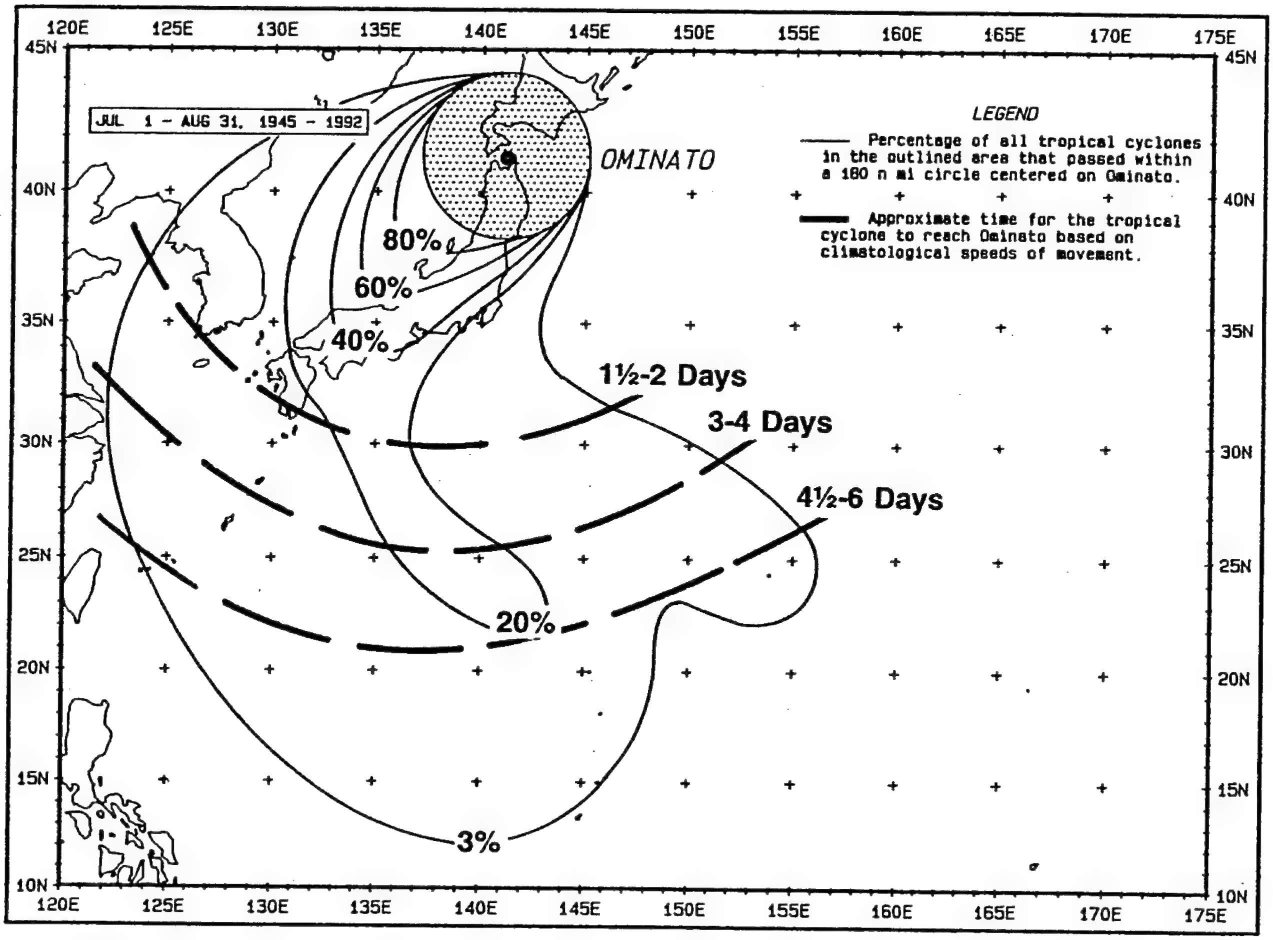

Figure V-190. Probability that a tropical storm or typhoon will pass within 180 nmi of Ominato (circle), and approximate time to closest point of approach, during July and August.

The solid lines on the figures represent a "percent threat" for any tropical cyclone location within the depicted area. The heavy, dashed lines represent the approximate time in days for a system to reach Ominato. For example, in Figure V-190, during the months of July and August a tropical cyclone located at 30°N 135°E has an approximate 25% probability of passing within 180 nmi of Ominato and would reach Ominato in about 1-1/2 to 2 days.

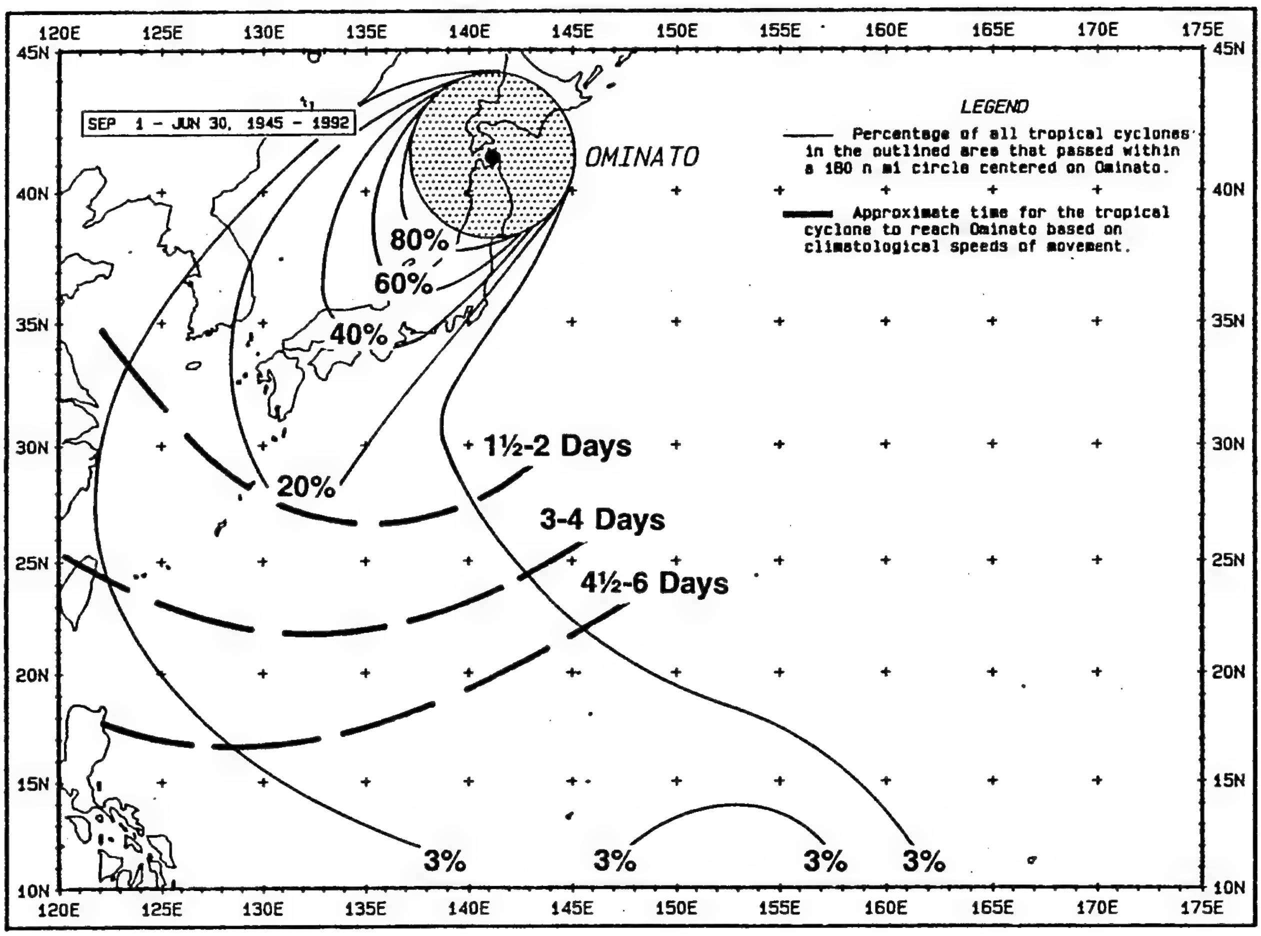

Figure V-191. Probability that a tropical storm or typhoon will pass within 180 nmi of Ominato (circle), and approximate time to closest point of approach, during the period September through June.

A comparison of Figures V-190 and V-191 shows that the threat axes for the two time periods are similar, with only minor differences distinguishing one from the other. North of 35°N, the primary axes are oriented southwestward from Ominato along the west coast of Honshu to approximately 35°N. Both axes extend southward between 35°N and 30°N and then turn southeastward south of 30°N.

Because of Ominato's northerly location, essentially all of the storms that enter its 180 nmi threat radius have recurved and their movement is being influenced by upper level westerly winds. Consequently, they are moving in a general north to northeasterly direction. To pass within 180 nmi of Ominato, most storms cross southern Honshu between 131°E and 140°E and approach Ominato through the eastern Sea of Japan. A few pass through the Tsushima (Korea) Strait or across southern Korea before entering the Sea of Japan. North of 35°N, some travel northward over land, paralleling the Japanese Alps along the length of Honshu.

14.5.2 Wind and Topographical Effects

The Port of Ominato has no wind measuring equipment. The Mutsu establishment of the Japan Atomic Energy Research Institute has a "wind gauge" on one of its wharfs in Ashizaki Bay, but its exact location is uncertain. The gauge is reportedly located on the end of Shimokita Wharf, but available charts do not identify wharfs and piers by name. The availability of the wind gauge readings for use by ships entering the port is not known.

The location of the port with respect to surrounding topography would make winds fairly representative of general wind flow when winds are from the east clockwise through south.

However, Kamabuse Mountain, a conical 2,881 ft (878 m) volcanic peak located about 3 nmi west of the mouth of Tanabu River (Figures V-185 and V-186), may enhance northeasterly or southwesterly winds at the port. Northwesterly winds will likely reach the port as westerly or northerly and be weakened somewhat by the generally rugged terrain northwest of the port. Regardless of direction, however, ships in the port are unprotected from wind flow, and will feel the full effects of the force of the wind.

14.5.3 Local Weather Conditions

A total of 10 tropical storms or typhoons passed within 180 nmi of Ominato during the 11-year period when observational data are available, 1982-1992. The data contained in Table V-47 have been selected from observations recorded at Ominato during the passage of the tropical cyclones listed in the table.[1] The listed winds represent the strongest wind recorded during the passage of each storm. No observational data are available for Ominato prior to 1982.

The latitude and longitude of the observation sites are listed on the record of observations as 41°14'N 141°08'E on some and 41°14'N 141°09'E on others. The sites are identified as station identifier 47516 (Ominato Japan Air Self Defense Force (JASDF)), and station identifier 47517, (Ominato). Either location places the observation site at or very close to a small airport located just south of Ashizaki Bay (Figure V-185).

[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

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Table V-47. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Ominato 1982-1992. Reported weather is the most severe reported during the entire passage of storm and did not necessarily occur coincident with the strongest winds.

TROPICAL CYCLONE DATA				MOST SEVERE LOCAL CONDITIONS	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	COMMENTS
82/09/12 (JUDY)	034/36	216/129	40	N 50G63	MDT/HVY RAIN SHOWERS
85/09/01 (RUBY)	042/20	151/140	45	WSW 56G67	LIGHT RAIN SHOWERS
89/08/27 (ROGER)	024/27	261/23	40	SE 42G51	MDT RAIN
90/08/24 (ZOLA)	071/35	358/26	45	W 28G40	LIGHT RAIN SHOWERS
90/09/20 (FLO)	062/35	160/106	53	NNE 26G36	MDT/HVY RAIN SHOWERS
90/12/01 (PAGE)	010/24	179/111	45	SW 48G65	LIGHT RAIN SHOWERS
91/09/27 (MIRIELLE)	048/58	053/10	63	SW 52G72	MDT/HVY RAIN SHOWERS

Figures V-192 and V-193 show tracks and track segments of tropical cyclones considered to have a high probability of having produced sustained winds ≥22 kt and ≥34 kt over water near Ominato during the 49-year period 1945-1993. It should be noted that the two figures are derived from theoretical calculations rather than actual wind observations. The calculated figures are presented because real-time observational data are available only for the relatively short 11-year period 1982-1992. Figures V-192 and V-193 are based on: (1) storm intensity (maximum wind near center), (2) distance of the storm center from Ominato, (3)

bearing of the storm from Ominato, (4) translational speed of the storm, and (5) frictional characteristics of the terrain between the storm and Ominato.

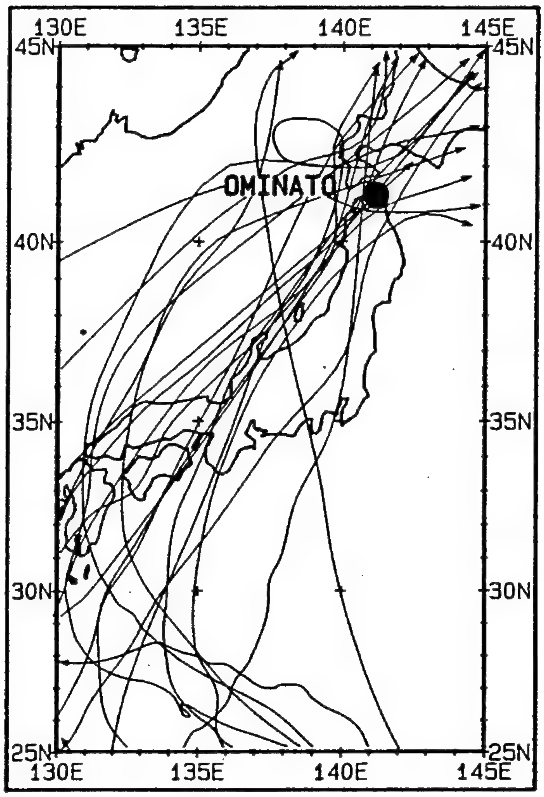

Figure V-192A.

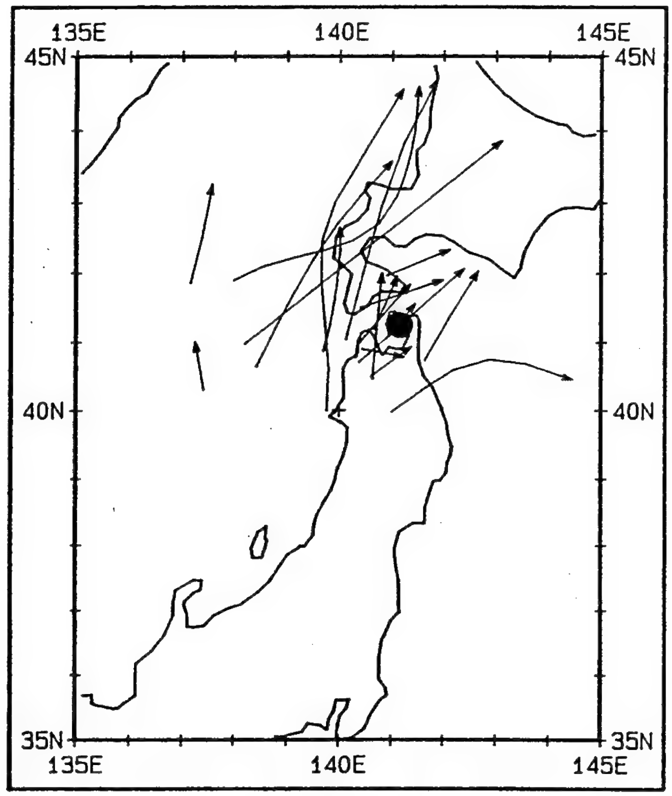

Figure V-192B.

Figure V-192. Tropical cyclones with a high probability of having produced sustained winds ≥22 kt at Ominato during the 49-year period 1945-1993. Figure V-192A shows tracks of the 19 high probability tropical cyclones, while Figure V-192B shows track segments of the same storms when ≥22 kt winds were most likely to have occurred at Ominato. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

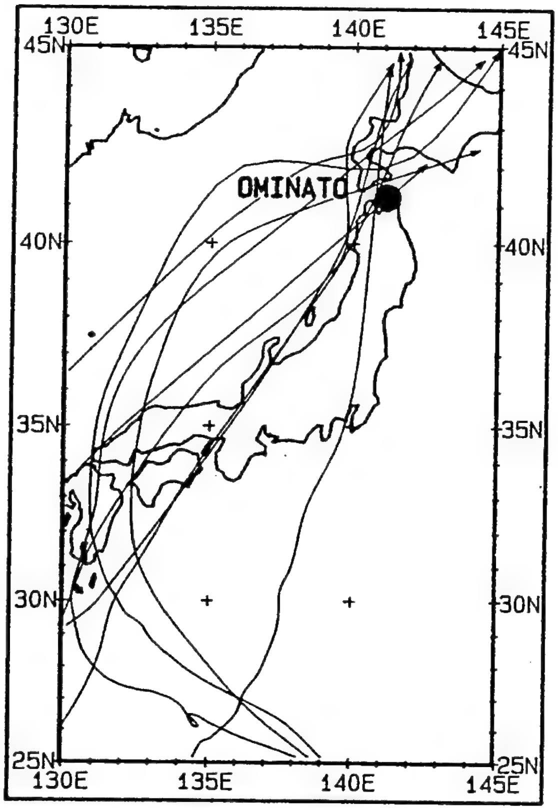

Figure V-193A.

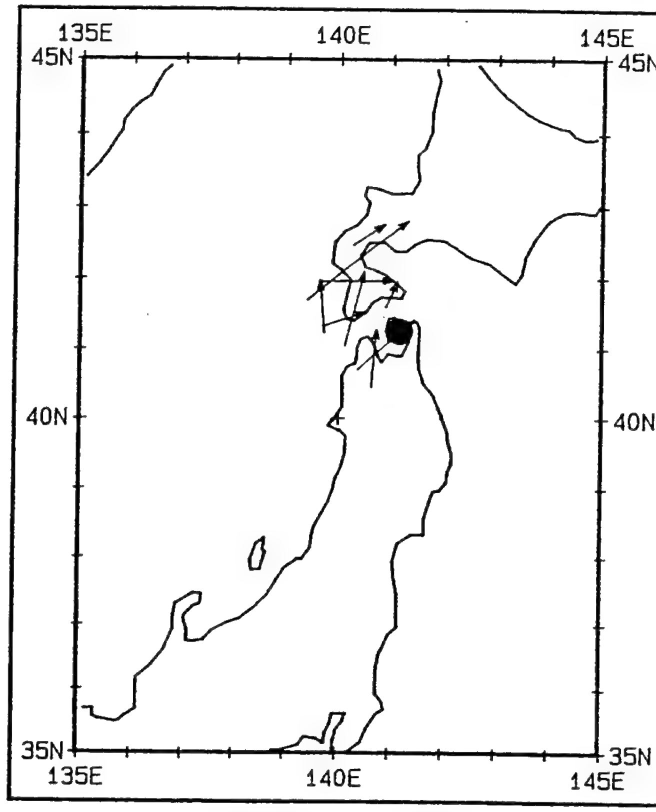

Figure V-193B.

Figure V-193. Tropical cyclones with a high probability of having produced sustained winds ≥34 kt at Ominato during the 49-year period 1945-1993. Figure V-193A shows tracks of the 9 high probability tropical cyclones, while Figure V-193B shows track segments of the same storms when ≥34 kt winds were most likely to have occurred at Ominato. The winds are based on theoretical calculations rather than actual observations. See text for further explanation.

14.5.4 Wave Motion

The location of the Port of Ominato in the extreme northeast part of Mutsu Bay limits the threat of hazardous wave motion at the port. The protective spit of land defining the east side of Ashizaki Bay effectively protects any vessel anchored or moored in the bay from any significant wave motion. Ships moored near the mouth of the Tanabu River may feel some

refracted wave motion if strong south to west-southwesterly winds are blowing across Mutsu Bay. The wave motion would likely be parallel to the longitudinal axis of the moored ships. It is also possible that waves reflected from the north side of the river could reach the berths. The berths on the south side of the river are well protected from all other directions.

The only portions of the port liable to feel the full effects of south to west-southwesterly wave motion are the berth on the north side of the Tanabu River near its mouth, and the exposed area of the bay lying between Ashizaki Bay and the mouth of the Tanabu River. There is a 24 nmi long fetch south of the port and a 32 nmi fetch to the southwest. Given those fetch limitations, a sustained wind from south clockwise through west-southwest of minimum gale force (≥34 kt) can theoretically raise waves of about 6 to 8 ft at the port. Because of the fetch limitations, waves greater than 8 ft are improbable, even with storm strength (≥47 kt) winds.

14.5.5 Storm Surge

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

The location of Ominato on Mutsu Bay effectively precludes any threat of storm surge at the port. In fact, no location on Mutsu Bay appears to be at significant risk from storm surge. The semi-enclosed configuration of relatively small Mutsu Bay, the northward facing bay entrance, and the bay's location on the north end of Honshu where rapid storm movement is common, all suggest that Ominato has a negligible storm surge threat. A local Mutsu City official could recall no past occurrences of storm surge at the port.

14.6 THE DECISION TO EVADE OR REMAIN IN PORT

14.6.1 General

The exposure of the port facilities at Ominato to the effects of wind precludes any decision to remain in the port during a strong wind event. This conclusion is applicable to all locations. Although wave motion is relatively benign in many wind situations, there is no protection from wind.

14.6.2 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when his/her ship is exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/JTWC) Guam tropical cyclone warnings, and a basic

understanding of weather, will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures V-190 and V-191, discussed earlier, address the probability of existing tropical cyclones later affecting Ominato. Figures V-194 and V-195 have been prepared as additional aids for the commander to use when evaluating a given situation. In contrast to Figures V-190 and V-191, Figures V-194 and V-195 consider only those storms which later passed within 180 nmi of Ominato. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered as an average approach scenario insofar as Ominato is concerned. It must be stressed that the other 50% of the storms which later affect Ominato will be outside of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures V-194 and V-195.

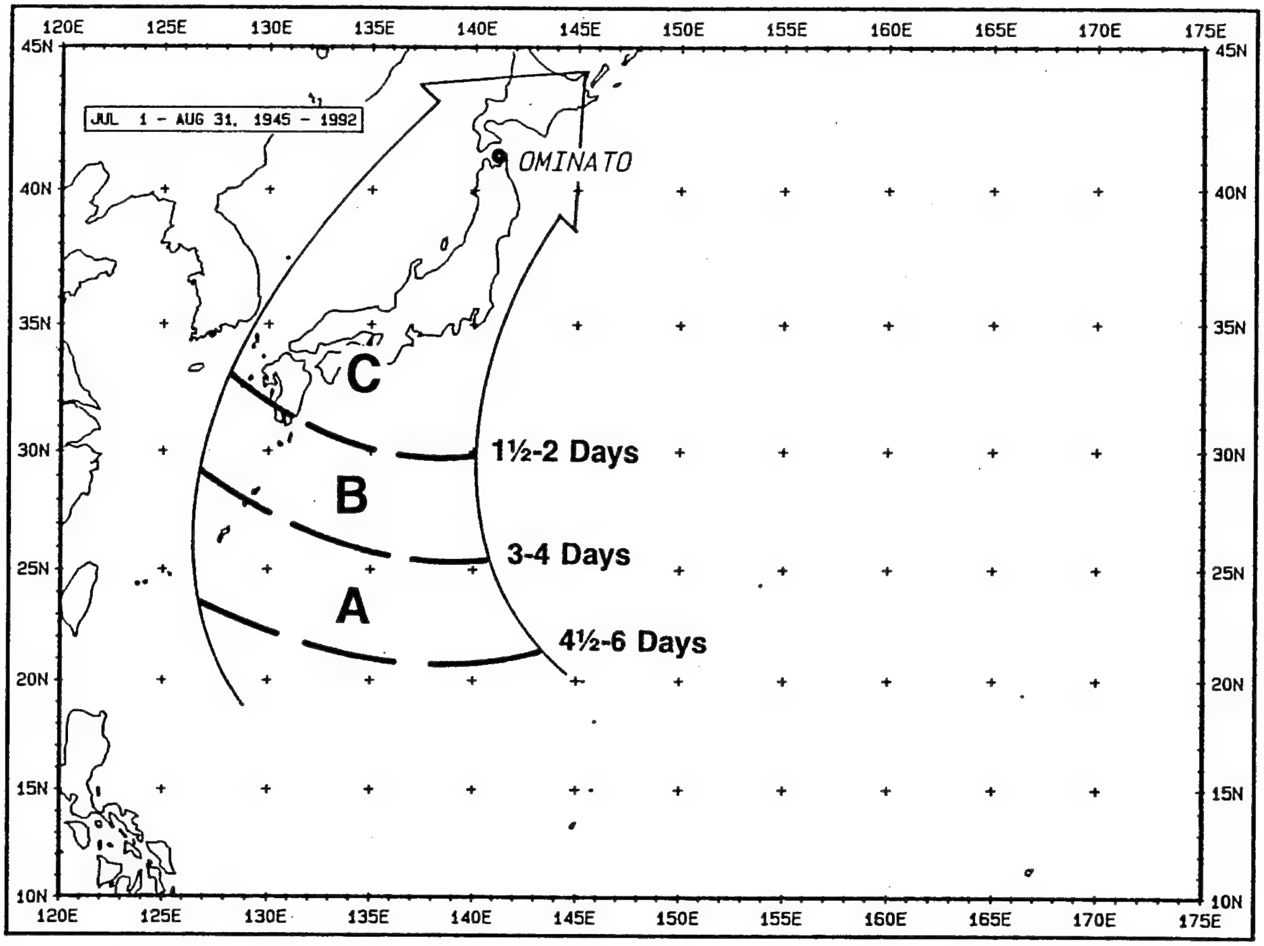

Figure V-194. For the tropical cyclones passing within 180 nmi of Ominato during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Ominato. See Figure V-190 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Ominato.

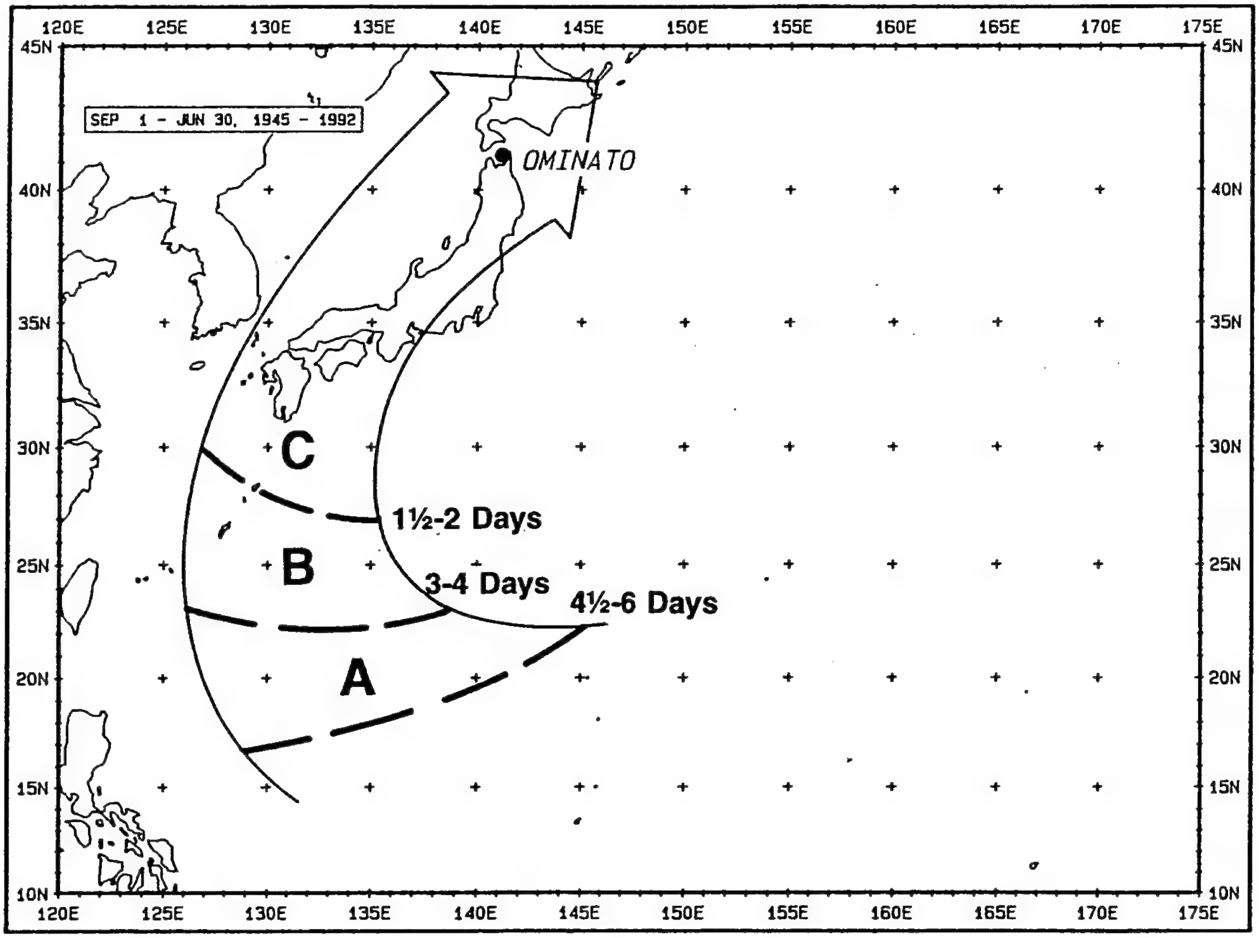

Figure V-195. For the tropical cyclones passing within 180 nmi of Ominato during the period September through June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Ominato. See Figure V-191 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Ominato.

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With the above restrictions in mind, the following time/action sequence aids, to be used in conjunction with Figures V-194 and V-195, are provided.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast toward Ominato:

a. Review material condition of ship.

b. Formulate plans for expeditious sortie from the Mutsu Bay and evasion route to be taken in the event the tropical cyclone threatens Ominato.

c. Reconsider any maintenance that would render the ship incapable of getting under way, if need be, within 48 hours.

d. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Ominato (recall that tropical cyclones tend to accelerate rapidly after recurvature).

a. Reconsider any maintenance that would render the ship incapable of getting underway, if need be, within 24 hours.

b. Finalize plans for expeditious sortie from the harbor and evasion route to be taken in the event the tropical cyclone threatens Ominato.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone has entered Area C and is moving toward the Ominato area:

a. Sortie from the harbor and Mutsu Bay, taking an evasion route that will allow the unit to encounter the most favorable weather conditions during the passage of the tropical cyclone.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

14.6.3 Evasion at Sea

Evasion routes at sea may be developed by using NPMOCW/ JTWC tropical cyclone warnings (see Chapter I), and Appendix A (Bi-Weekly Tropical Storm and Typhoon Tracks for the Western North Pacific Ocean) for the period of interest. They should be used in conjunction with Figures V-190 and V-191 (tropical cyclone threat axes and approach times to Ominato). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

Two basic evasion routes are available: (1) exiting Mutsu Bay and moving west through Tsugaru Strait into the Sea of Japan, and (2) exiting Mutsu Bay and moving east through Tsugaru Strait into the Pacific Ocean and proceeding south along the east coast of Honshu. If the tropical cyclone is moving northeastward on a track that would take it east of Mutsu Bay, moving into in the Sea of Japan would keep the vessel on the weaker, left side of the storm's circulation and avoid the strongest winds of the storm. However, the ship may be exposed to relatively strong winds from the northwest quadrant as the storm passes and high pressure moves into the Sea of Japan behind the storm's circulation.

If the storm is forecast to pass west of Mutsu Bay, moving through Tsugaru Strait into the Pacific Ocean and proceeding south along the east coast of Honshu should be considered. It must be emphasized that this option has a potentially serious drawback. If the tropical cyclone should move east of the forecast track, and therefore closer to the

ship's evasion route, the ship may encounter the strong winds of the storm's dangerous semicircle. In a best case situation, depending on the size of the storm's circulation the ship may still be liable to encounter strong southerly winds along the coast. However, the winds should be short lived because of the historically rapid movement of tropical cyclones when they reach the latitudes of northern Japan.

Regardless of the option chosen, it is of utmost importance to begin the sortie as early as possible. It is approximately 40 nmi from Ominato to the open waters of Tsugaru Strait, and another 50 nmi to the east coast of Honshu. At a steaming speed of 20 kt, it will take approximately 4 to 5 hours to complete the transit. If the tropical cyclone has recurved before the sortie is commenced, and is moving at 30 kt, the storm could be 150 miles (or more) closer to Ominato by the time the east coast of Honshu is reached. It should be noted that the average speed of movement of tropical cyclones occurring during the 48-year period 1945-1992 is 35 kt when at CPA to Ominato (Table V-45). Those occurring during September <u>average</u> a relatively rapid 38 kt, so many storms will move faster. Six of the storms listed in Table V-45 have speeds in excess of 50 kt when at CPA to Ominato and one, tropical storm Tip in October 1979, had a forward speed of over 73 kt.

It must be remembered that tropical cyclones are notoriously difficult to accurately forecast, especially in the recurvature phase; the 48-hour forecast position error may exceed 200 nmi. A storm may be closer to or farther from Ominato than the forecast indicates, or right or left of the storm's forecast track. Each tropical storm or typhoon must be considered as differing from those preceding it. The accompanying synoptic situation must be fully understood. To blindly establish and follow only one technique or rule for avoiding a storm's danger

area is not prudent and, in fact, may ultimately place the ship in harm's way.

REFERENCES

FICPAC, 1992: Port Directory for Otaru, Japan, Change 20. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with Mr. Nobuhide Nara, Chief, Harbor Section, Mutsu Public Works, Aomori Prefecture to obtain much of the information contained in this port evaluation.

15. YOKOHAMA

SUMMARY

The conclusion reached in this study is that the Port of Yokohama is not a typhoon haven. The primary factors in reaching this conclusion are: (1) Mizuho Wharf, where U. S. Navy ships would most likely moor, offers no protection from wind, and (2) Local port authorities state that ships should leave their berths if winds of 30 kt or greater are forecast.

The best option for U. S. Navy ships in the Port of Yokohama is to move to Fleet Activities, Yokosuka before the onset of any storm. Yokosuka is considered to be a "safe" typhoon haven; a port in which to remain if already there, or one in which to seek shelter if at sea or elsewhere when threatened by a tropical cyclone.

Ships may move to the Nakano Se anchorage just southeast of the port to ride out a tropical cyclone. Vessels should be ready to steam to the anchor to reduce strain on the anchor chain and lessen the threat of anchor dragging during the strongest winds. Other options include moving to anchor at various other locations within Tokyo Bay or evading at sea.

15.1 LOCATION

The Port of Yokohama, one of Japan's busiest deep water ports, is located at 35°27'N 139°40'E on the southeast coast of Honshu, the largest of the four main islands of Japan (Figure V-196).

Yokohama is situated on the west side of Tokyo Bay. Except for its 4.75 nmi wide southern entrance, Tokyo Bay is surrounded by land. As can be seen in Figure V-197, the Port of Yokohama is located between two other important and busy ports, Tokyo and Yokosuka. Tokyo is located approximately 10 nmi northeast of Yokohama, and Yokosuka is approximately 10 nmi south of Yokohama. Over 200 ships transit Uraga Suido, a controlled traffic route through the congested entrance to Tokyo Bay, daily.

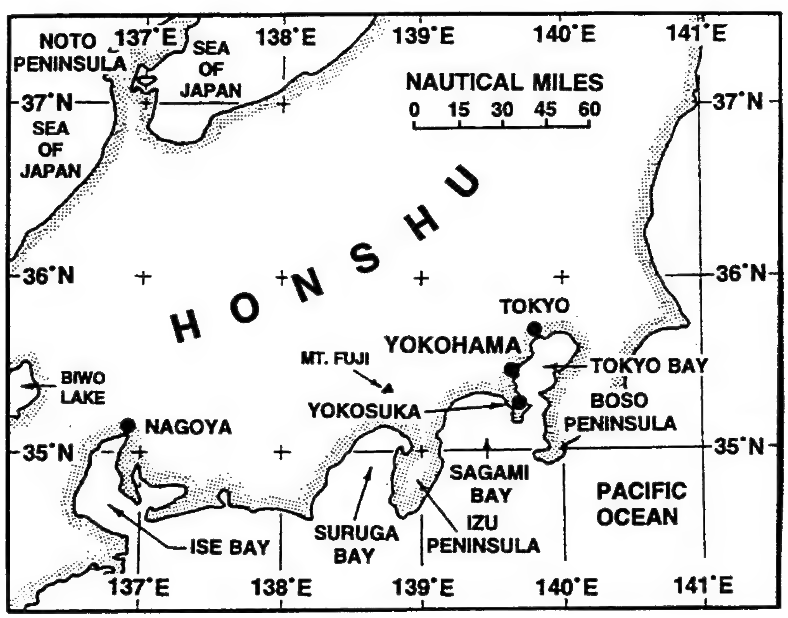

Figure V-196. Location of Yokohama in the southeastern portion of Honshu.

15.2 YOKOHAMA HARBOR

Yokohama harbor is situated on the west side of Tokyo Bay. The Port of Yokohama encompasses a total water area of approximately 18,522 acres (28.94 mi^2), counting the portions of rivers and canals that are also under the Port of Yokohama's jurisdiction. The Port abuts on the Port of Kawasaki to the northeast. Negishi Bay, with its many industrial facilities, is situated just south of the main Port of Yokohama. Negishi Bay is included within the greater Yokohama Port area. Yokohama is a busy port, having an average of 32 deep-draft vessels entering the port each day (1991 statistic). The combined ports of Yokohama and Kawasaki are called the port of "Keihin-ko."

The inner portion of the Port of Yokohama is entered via 700 yd (640 m) wide Yokohama Passage which narrows to 416 yd (380 m) as it passes under the Yokohama Bay Bridge (Figure V-198). The bridge has a vertical clearance of 180 ft (55 m) in the center of the span and 174 ft (53 m) on either side.

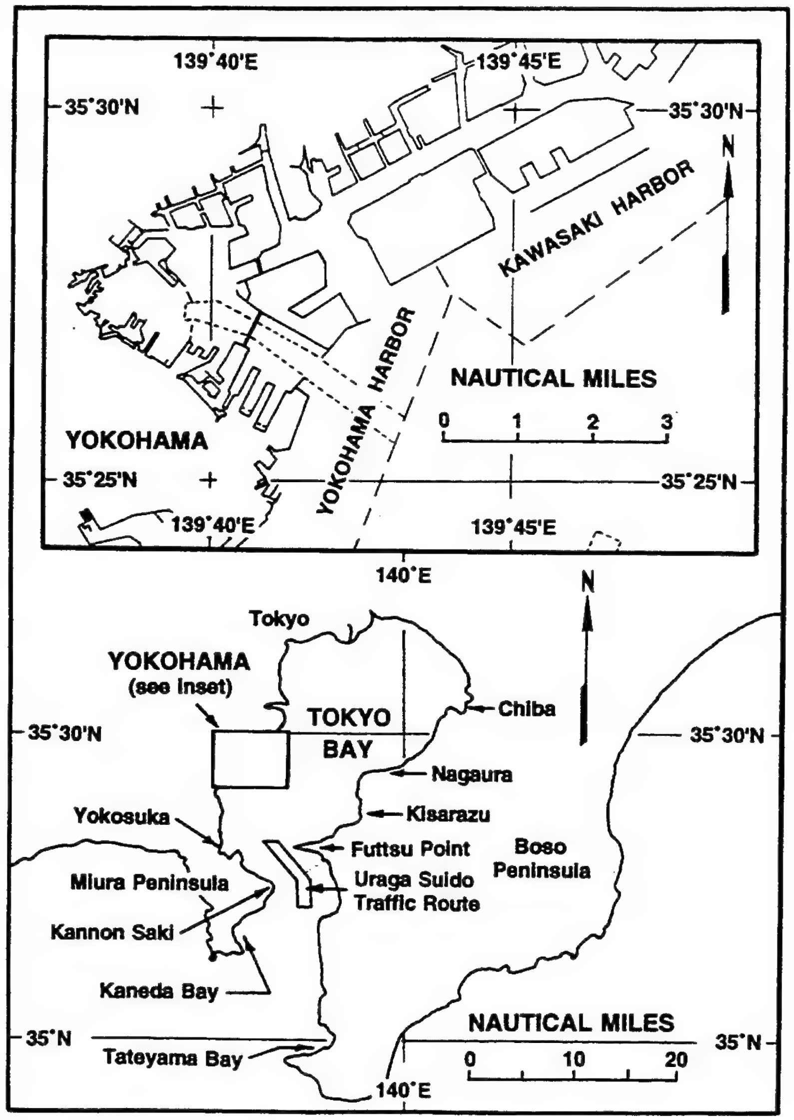

Figure V-197. Tokyo Bay and the surrounding land area. See inset for enlargement of Yokohama region.

Currents at or near the Port of Yokohama are primarily wind and tide driven and do not generally pose a problem to navigation. According to a local harbor chart, a flooding tidal current sets in from the outer breakwaters at an average rate of not more than 1 kt (0.5 m s^{-1}). The ebb current flows out at a slower rate. The currents in the navigation channels outside the outer breakwaters are the strongest of all currents inside and outside the port, but they are limited to 2 kt (1.0 m s^{-1}).

Astronomical tidal range at the port is relatively small. The average high tide is only 2.8 ft (0.84 m) above mean sea level (msl). The average low tide is -3.45 ft (-1.05 m) below msl. Extreme high tide recorded at the port is 5.25 ft (1.6 m) above msl. The extreme low tide is -5.18 ft (-1.58 m) below msl.

5.3 HARBOR FACILITIES

The Port of Yokohama has 112 commercial deep draft berths with mooring capacities varying from 40,000

DWT (2 berths) to less than 3,000 DWT (15 berths) (Port of Yokohama Promotion Association, 1992). Additionally, there are approximately 165 privately controlled berths in the port that range in size from super-tanker berths that can accommodate 90,000 DWT tankers to several berths that are limited to less than 1,000 DWT. Figure V-198 shows the general pier configuration at the port. According to port authorities, all pier faces have built-in rubber fenders.

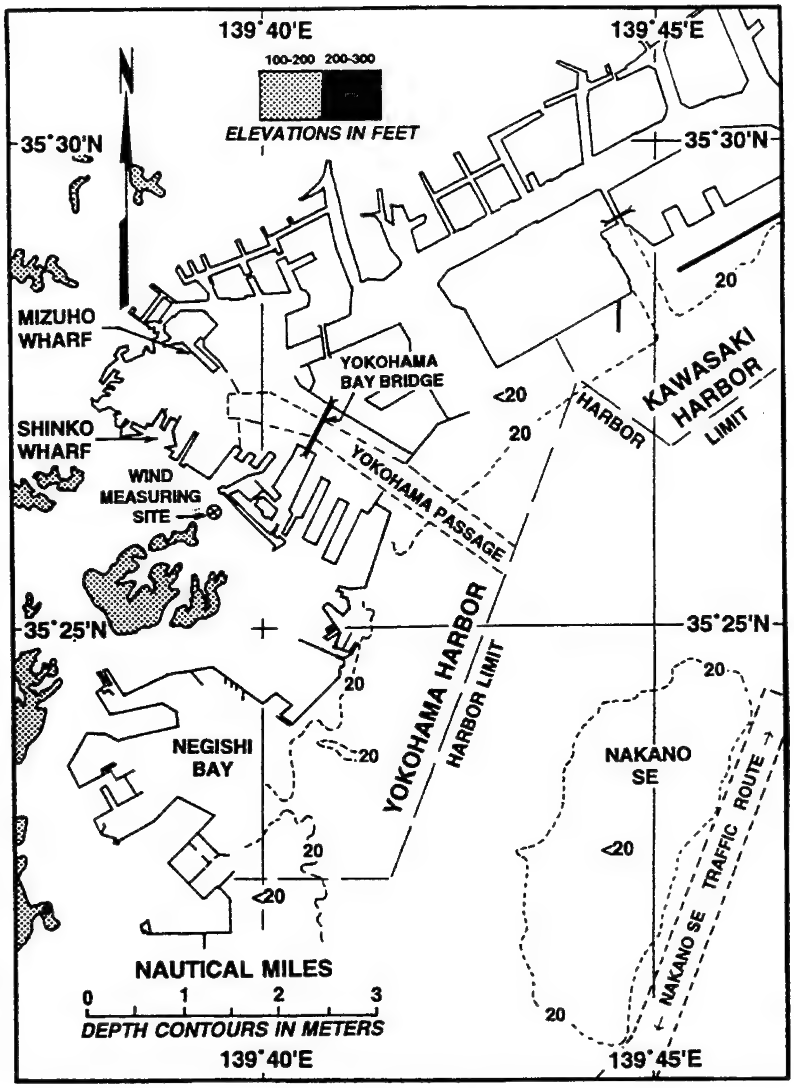

Figure V-198. Port of Yokohama.

The facilities of primary interest to this study are the seven berths at Mizuho Wharf, as they are used only by U. S. Military ships (Figures V-198 and V-199a). Five of the berths are 623 ft (190 m) long, with apron widths of 49 ft (15 m). They can accommodate ships to 15,000 DWT. The two remaining berths are 502 ft and 512 ft (153 and 156 m) long with apron widths of 49 ft (15 m). They can accommodate ships to 8,000 DWT. Alongside depths vary from 29.5 to 32.8 ft (9 to 10 m).

The Guide to the Port of Yokohama also lists berth number 7 at Shinko Wharf (Figures V-198 and V-199b) as being used by U. S. Military ships only, but the berth was not mentioned by harbor authorities during a port visit in September 1993. Specific data on the berth are not available, but measurements taken from a harbor chart indicate the berth is approximately 525 ft (160 m) long. Available documentation indicates that all berths on Shinko Wharf have alongside depths of 27.5 to 33.5 ft (8.4 to 10.2 m).

Several anchorages for general vessels and vessels carrying dangerous cargo are available immediately adjacent to the Ports of Yokohama, Kawasaki and Negishi Bay. Anchorages are designated by the Captain of Keihin-ko. Local authorities state that the safest anchorage, and the one recommended for use by U.S. Navy ships, is Nakano Se (Shoal). It is located southeast of the port, immediately west of the northern portion of the Nakano Se Traffic Route (Figure V-198). Depths in the anchorage vary mostly from 49 to 65 ft (15 to 20 m), but are as shallow as 39 ft (12 m) near the extreme northern part of the anchorage. Holding is said to be good on a bottom of mostly mud, sand and clay. The bottom in some areas of the anchorage is composed of sand and shells.

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The use of harbor pilots is generally recommended, but if tug boats are used, a pilot is often not necessary. A total of 34 tug boats are available for use at the port.

Extensive ship repair facilities exist at the port, with five dry docks, many heavy lift cranes, and other heavy duty equipment available. However, the close proximity of Fleet Activities, Yokosuka in relation to Yokohama would dictate that most dry docking, repairs and maintenance of U. S. Navy ships would be performed at Yokosuka.

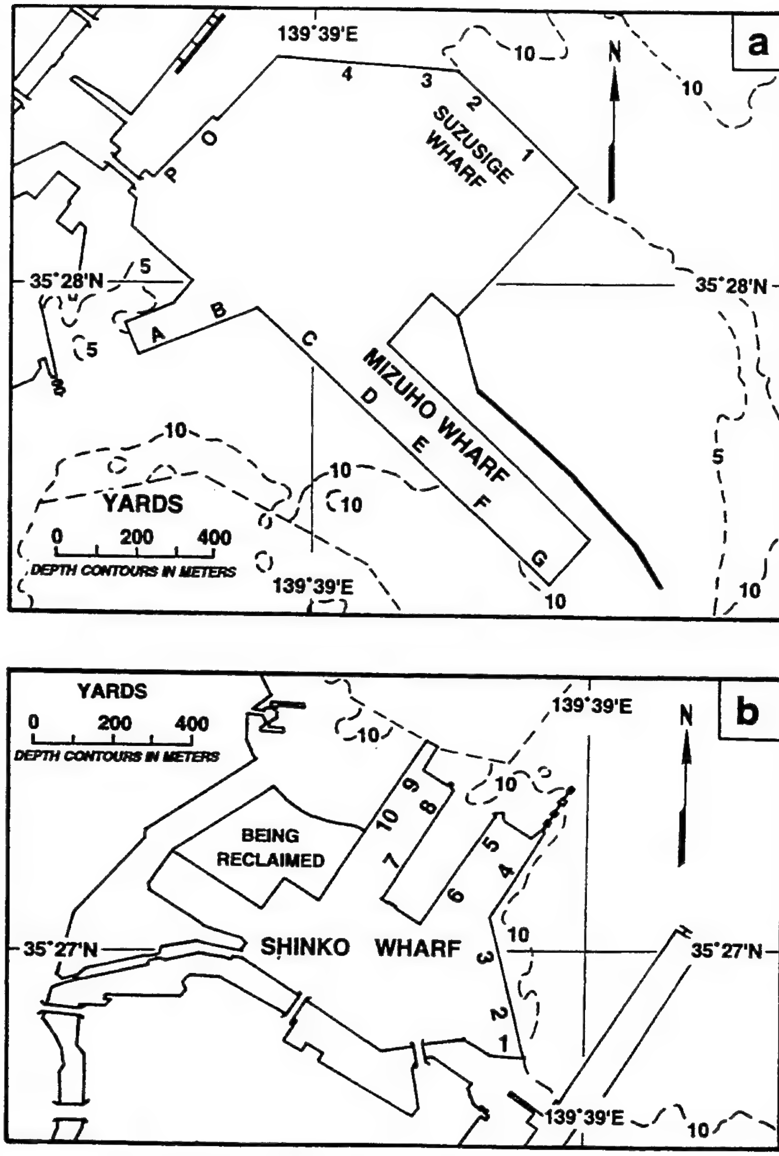
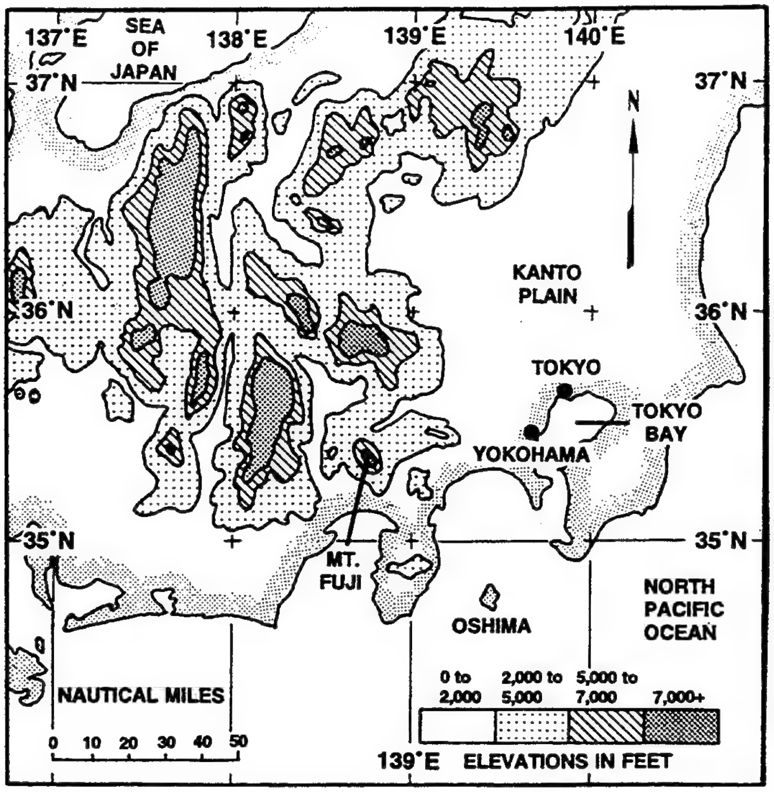


Figure V-199. (a) Mizuho and (b) Shinko wharves at Yokohama.

15.4. TOPOGRAPHY

As described by the locally produced Guide to the Port of Yokohama, the Port of Yokohama is "Surrounded by moderately rolling hills on the north, west and south" and open to the sea on the east. Some of the hills are evident on Figure V-198. High mountains dominate Honshu to the west and northwest of Yokohama (Figure V-200). The mountains of north central Honshu average 5,000 to 10,000 ft (1,524 to 3,048 m) in height and are often called the Japanese Alps. The highest mountain, 12,395 ft (3,778 m) Mount Fuji, is located about 60 nmi west-southwest of Yokohama. Northern and southern Honshu's terrain is less rugged than central Honshu; southern Honshu has no peaks rising over 5,000 ft (1,524 m). The mountainous terrain of Honshu has a major influence on Yokohama's weather.



Topography of central Honshu.

15.5 TROPICAL CYCLONES AFFECTING YOKOHAMA

15.5.1 Tropical Cyclone Climatology at Yokohama

For the purpose of this evaluation, any tropical storm or typhoon approaching within 180 nmi of Yokohama is considered to represent a threat to the port. Table V-48 contains a descriptive history of all tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992. All of the tropical cyclone statistics used in this report for storms passing within 180 nmi of Yokohama are based on the data set used to compile Table V-48.

Tropical cyclones which affect Japan generally form in the area bounded by 5°N to 30°N and 120°E to 165°E. In response to the seasonal changes of the synoptic environment, the latitudinal boundaries shift poleward during the summer months and then equatorward in winter. Considering the entire western North Pacific basin, about two-thirds of the tropical cyclones reach at least typhoon intensity at some point in their life cycle.

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Table V-48. Descriptive history of the 112 tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992. Forward speed at closest point of approach (CPA) is in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	OPAL	1945	JUL	21	6	37	85 (ESE)	024/15.2
2	GRACE	1945	AUG	22	12	40	174 (SSE)	320/ 9.1
3	IDA	1945	SEP	18	18	55	46 (NW)	056/31.5
4	KATE	1945	OCT	5	22	43	22 (SE)	137/47.3
5	LOUISE	1945	OCT	11	23	47	103 (WNW)	027/32.2
6	GWEN	1947	AUG	7	7	40*	47 (SSE)	078/19.2
7	KATHLEEN	1947	SEP	15	11	52*	9 (S)	041/19.3
8	BERTHA	1948	AUG	6	8	37	101 (E)	009/10.1
9	IONE	1948	SEP	16	14	77	6 (WNW)	046/26.0
10	LIBBY	1948	OCT	6	17	60*	55 (SSE)	067/21.1
11	AGNES	1948	NOV	19	23	53	25 (S)	059/32.2
12	KITTY	1949	AUG	31	9	54*	14 (WNW)	358/19.0
13	PATRICIA	1949	OCT	27	17	85	160 (SE)	054/34.8
14	JANE	1950	SEP	3	8	58	171 (WNW)	032/27.7
15	MISSATH	1950	SEP	19	11	48	79 (SE)	028/38.9
16	RUBY	1950	OCT	31	14	80	143 (SE)	030/32.9
17	KATE	1951	JUL	2	5	58*	29 (SSW)	087/30.4
18	RUTH	1951	OCT	15	11	48	99 (N)	076/31.3
19	DINAH	1952	JUN	23	2	50	23 (ESE)	066/33.5
20	JEANNIE	1952	AUG	8	7	29	89 (ESE)	030/17.8
21	LOLA	1953	AUG	1	6	65	102 (ESE)	027/14.5
22	MAMIE	1953	AUG	7	7	35	113 (ESE)	029/10.9
23	TESS	1953	SEP	25	15	63*	80 (NNW)	051/33.1
24	GRACE	1954	AUG	19	4	30	137 (W)	075/11.2
25	LORNA	1954	SEP	18	11	58*	18 (SSE)	042/31.3
26	ELLEN	1955	JUL	22	7	39	145 (SE)	045/16.9
27	FRAN	1955	JUL	20	8	33	143 (SE)	038/14.4
28	TS5550	1955	JUL	19	9	40	145 (SE)	041/18.8
29	NORA	1955	OCT	11	18	76	66 (SE)	047/30.1
30	OPAL	1955	OCT	20	19	43	73 (NW)	055/54.9
31	HARRIET	1956	SEP	27	15	70	171 (WSW)	052/28.0
32	VIRGINIA	1957	JUN	28	5	20	131 (W)	044/ 5.7
33	BESS	1957	SEP	7	9	50	167 (NW)	043/37.6
34	FAYE	1957	SEP	27	13	67	134 (SSE)	066/42.5
35	JUDY	1957	OCT	25	18	65	162 (SE)	047/13.5
36	ALICE	1958	JUL	23	9	50*	4 (SSE)	036/26.7
37	FLOSSIE	1958	AUG	25	12	36	24 (N)	068/21.8
38	HELEN	1958	SEP	17	14	82	27 (SE)	047/32.4
39	IDA	1958	SEP	26	15	70	15 (SE)	014/25.6
40	ELLEN	1959	AUG	9	6	50	8 (N)	073/20.4
41	GEORGIA	1959	AUG	13	7	83	50 (WSW)	346/35.0
42	VERA	1959	SEP	26	15	103	129 (WNW)	030/35.5
43	AMY	1959	OCT	7	16	42	49 (SSE)	083/46.4
44	CHARLOTE	1959	OCT	18	18	60	114 (SE)	052/35.9
45	WENDY	1960	AUG	13	11	45	160 (NNW)	059/30.3
46	BESS	1960	AUG	20	13	65	63 (SE)	037/17.7
47	FAYE	1960	AUG	30	17	66	130 (ESE)	023/20.3
48	NANCY	1961	SEP	16	18	68	144 (WNW)	033/45.4
49	VIOLET	1961	OCT	9	23	67	32 (SE)	037/26.8
50	LOUISE	1962	JUL	28	7	30	22 (NNW)	071/16.1
51	RUTH	1962	AUG	20	12	85	124 (ESE)	031/ 9.4
52	THELMA	1962	AUG	25	14	54*	170 (W)	358/21.0
53	POLLY	1963	JUN	5	2	65	126 (SE)	034/28.4
54	VIRGINIA	1963	JUL	9	6	38	102 (SSE)	060/37.4
55	DELLA	1963	AUG	28	11	70	61 (SSE)	070/14.9
56	KATHY	1964	AUG	24	15	55	162 (NW)	046/17.6
57	WILDA	1964	SEP	25	24	58*	156 (NW)	046/51.9
58	AMY	1965	MAY	27	7	50*	32 (ESE)	034/45.7
59	LUCY	1965	AUG	22	18	53*	13 (W)	035/11.2
60	TRIX	1965	SEP	17	25	78	36 (WNW)	042/30.0

NOTES: Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.5°N, 139.7°E.

Table V-48 (continued). Descriptive history of the 112 tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992. Storm speed at closest point of approach (CPA) is in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
61	VIRGINIA	1965	SEP	16	26	48	163 (ESE)	028/24.4
62	WENDY	1965	SEP	25	27	43	156 (S)	077/16.1
63	KIT	1966	JUN	28	4	65	79 (SE)	040/31.7
64	VIOLA	1966	AUG	22	13	35	80 (SW)	319/21.3
65	IDA	1966	SEP	24	23	75	56 (WNW)	017/34.6
66	LOUISE	1967	AUG	23	15	35	110 (WSW)	059/ 1.8
67	OPAL	1967	SEP	14	20	60*	164 (SE)	045/14.1
68	DINAH	1967	OCT	28	30	56	65 (NW)	044/28.5
69	CORA	1969	AUG	23	9	33	52 (NNW)	060/30.9
70	FLOSSIE	1969	OCT	9	13	50	137 (SE)	049/47.6
71	CLARA	1970	AUG	28	11	77	129 (E)	006/ 5.1
72	IVY	1971	JUL	7	13	33	19 (N)	062/21.6
73	VIRGINIA	1971	SEP	7	24	70	101 (S)	033/16.2
74	CARMEN	1971	SEP	26	28	40	31 (NW)	072/27.5
75	PHYLLIS	1972	JUL	15	7	38	151 (W)	360/15.0
76	ALICE	1972	AUG	7	13	62*	74 (ESE)	015/16.4
77	HELEN	1972	SEP	16	20	62*	147 (WNW)	019/30.9
78	KATHY	1972	OCT	6	23	55	159 (SE)	045/35.3
79	ELLEN	1973	JUL	28	6	25	130 (WSW)	329/ 5.6
80	MARY	1974	AUG	26	15	38	69 (WNW)	027/34.6
81	RITA	1975	AUG	23	8	50	144 (NW)	047/30.3
82	CORA	1975	OCT	5	15	100	114 (SSE)	069/33.0
83	EMMA	1977	SEP	19	13	43	107 (ESE)	035/18.4
84	VIRGINIA	1978	AUG	1	7	55	98 (ESE)	028/14.1
85	OWEN	1979	SEP	30	19	43	88 (NNW)	043/46.6
86	TIP	1979	OCT	19	23	60*	68 (NW)	046/61.0
87	ELLEN	1980	MAY	21	4	35	106 (SE)	039/41.3
88	WYNNE	1980	OCT	14	23	70	91 (SSE)	066/38.6
89	THAD	1981	AUG	22	15	67	16 (NE)	013/29.5
90	GAY	1981	OCT	22	24	68	31 (SSE)	045/42.6
91	BESS	1982	AUG	1	11	53*	127 (W)	360/34.0
92	JUDY	1982	SEP	12	19	60*	114 (W)	001/26.1
93	ABBY	1983	AUG	17	5	45*	16 (WNW)	068/11.6
94	BEN	1983	AUG	14	7	45	58 (S)	284/21.2
95	IDA	1983	OCT	11	14	52	82 (SSE)	065/34.5
96	IRMA	1985	JUN	30	6	64	20 (SW)	047/42.5
97	RUBY	1985	AUG	30	14	45	8 (ESE)	015/14.5
98	MAC	1989	AUG	6	15	50*	63 (ENE)	336/17.6
99	ROGER	1989	AUG	27	20	40	147 (NW)	035/24.7
100	WAYNE	1989	SEP	19	25	58	33 (SE)	062/40.8
101	VERNON	1990	AUG	4	11	70	165 (SSE)	063/ 5.0
102	WINONA	1990	AUG	10	12	58*	30 (NW)	037/17.5
103	FLO	1990	SEP	19	20	63*	113 (NW)	035/33.4
104	GENE	1990	SEP	30	21	53	16 (ESE)	066/24.2
105	HATTIE	1990	OCT	8	22	43	13 (NE)	057/43.2
106	PAGE	1990	NOV	30	29	48	46 (WNW)	039/25.8
107	HARRY	1991	AUG	30	16	40	32 (NNW)	042/23.6
108	IVY	1991	SEP	9	17	90	157 (SSE)	062/17.9
109	KINNA	1991	SEP	14	19	53	129 (NNW)	072/34.6
110	LUKE	1991	SEP	19	20	45	87 (ESE)	030/42.7
111	ORCHID	1991	OCT	12	23	55	176 (SSE)	058/16.9
112	BOBBIE	1992	JUN	30	3	45	43 (SE)	053/41.0

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.5°N, 139.7°E.

Tropical cyclones are nurtured by a warm marine environment. In this basin maximum storm intensity typically occurs between 20°N and 25°N where sea-surface temperatures average near 84°F (29°C) during the month of August. After recurvature into the westerlies and the association with a colder environment, tropical cyclones lose their tropical characteristics. In this situation, the size of the circulation usually expands,

the speed of the maximum wind decreases, the translational (forward) speed of motion increases and the distribution of winds, rainfall and temperature becomes increasingly asymmetric. However, since Yokohama is located just north of the normal recurvature latitude, recurved tropical cyclones passing within 180 nmi of the port still retain many of their tropical characteristics.

Although tropical cyclones have occurred during all months in the genesis area described in the preceding paragraphs, the primary tropical cyclone season for Yokohama is from June through October. As shown in Table V-49, since 1945 storms have passed within 180 nmi of Yokohama as early as May and as late as November. None have been recorded during the months of December through April. Approximately 28% (31 of 112) of all tropical storms passing within 180 nmi were of at least minimum typhoon strength (≥64 kt) when at their closest point of approach (CPA) to Yokohama. None of the May and November storms were of typhoon strength when at their CPA to Yokohama.

Table V-49 also shows the motion history of the 112 tropical storms and typhoons which passed within 180 nmi of Yokohama during the period 1945-1992. The average movement for all storms when at CPA to Yokohama is 041 degrees at 27 kt.

Table V-49. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992.

Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Total number of storms passing within 180 n mi	0	0	0	0	2	6	11	37	32	22	2	0	112
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	3	0	9	11	8	0	0	31
Number of storms less than typhoon intensity at CPA	0	0	0	0	2	3	11	28	21	14	2	0	81
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	*	051	041	029	043	056	*	—	041
Average storm speed (knots) at CPA	—	—	—	—	*	30	19	18	31	36	*	—	27

** indicates insufficient storms for average direction and speed computations.*

The average storm speed at CPA to Yokohama ranges from 18 kt in August to 36 kt in October. As shown in Appendix A, most tropical cyclones that pass close to Yokohama recurve between 20°N and 30°N and then accelerate northeastward. Because Yokohama is north of the normal latitudinal recurvature range, most storms passing within 180 nmi of the port have already recurved and are moving northeastward under the influence of upper level westerlies.

Figure V-201 depicts the monthly distribution of all 112 storms that passed within 180 nmi of Yokohama during the period 1945-1992. Occurrence is shown in 7-day increments. The figure shows that the period of peak occurrence is from early August through mid-to-late October.

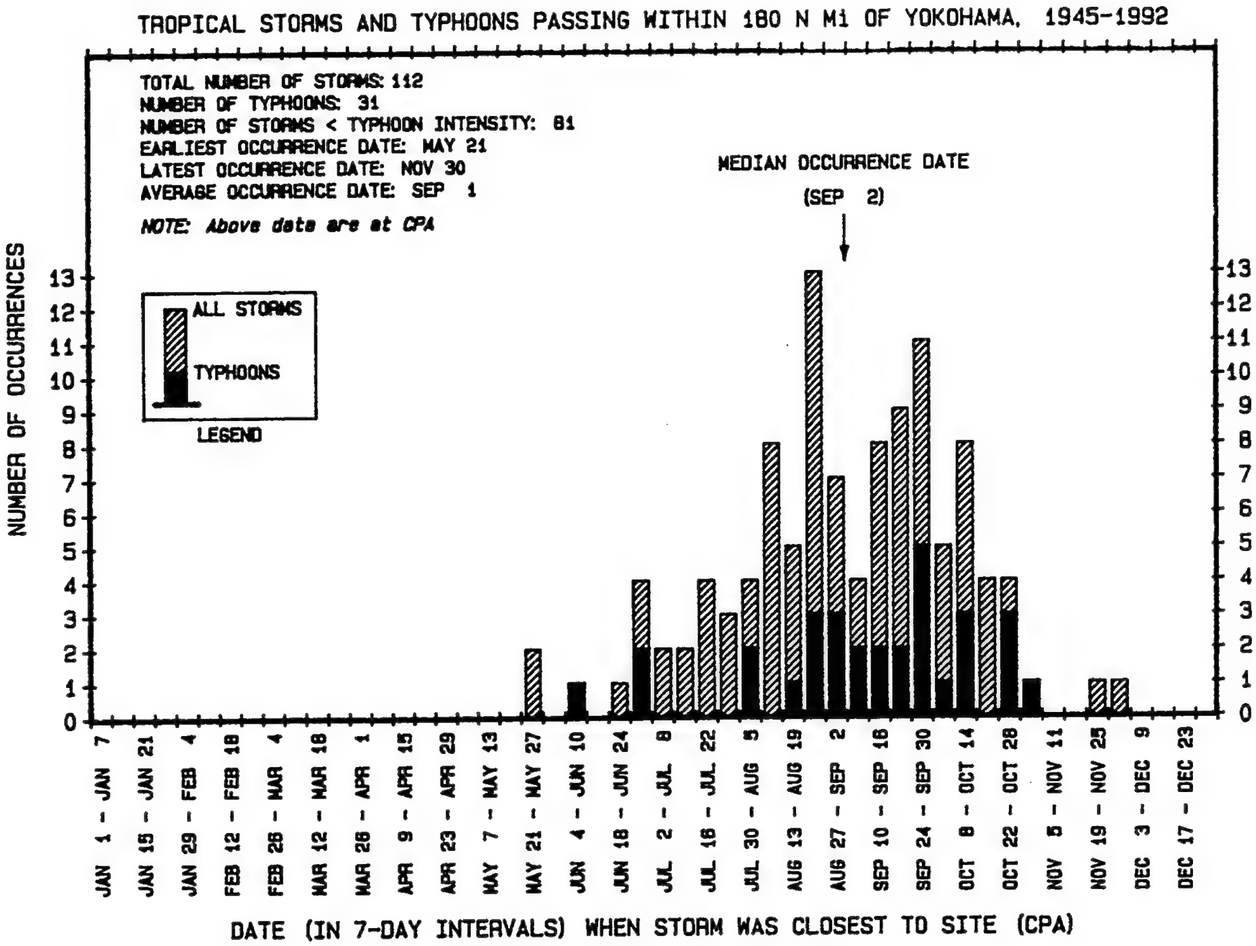

Figure V-201. Monthly distribution of the 112 tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992.

During the period from 1945 through 1992 there were 112 tropical storms and typhoons that met the 180 nmi threat criterion for Yokohama, an average of over two per year. Figure V-202 depicts the actual number of storms occurring each year during that 48-year period. The designation as a tropical storm or typhoon is based on the intensity of the storm at the time of CPA to Yokohama. It can be seen that most years had at least one occurrence, and some had as many as five storms. One year, 1990, had six storms pass within 180 nmi. Only seven of the 48 years shown had no occurrences. Considering that Yokohama lies in a region where tropical cyclone activity is a relatively common occurrence, an extremely atypical situation occurred in the three-year period 1986 through 1988, when no tropical storms or typhoons passed within 180 nmi of the port.

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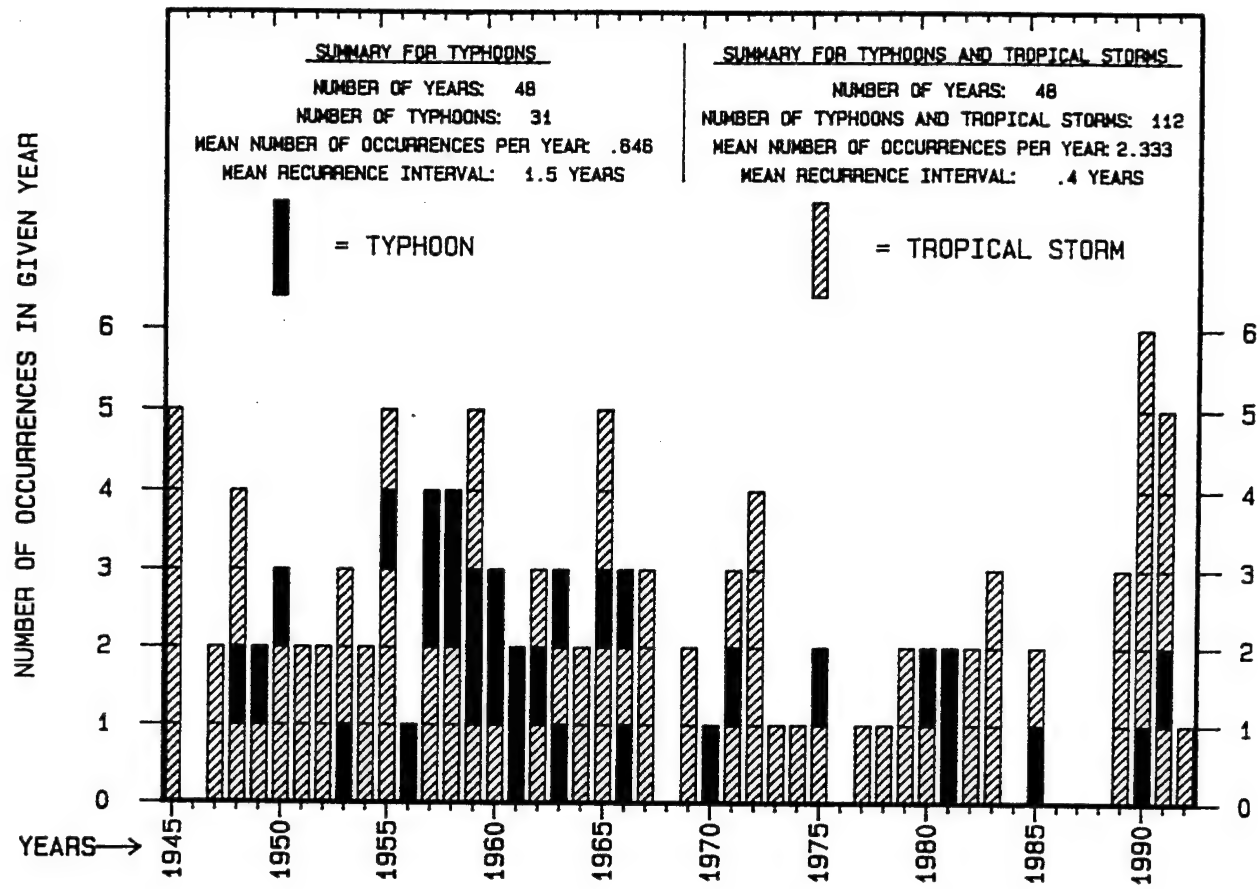

Figure V-202. Chronology of all tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992. The designation as a tropical storm or typhoon is based on the intensity of the storm at the time of CPA to Yokohama.

Figure V-203 depicts, on an 8-point compass, the octants from which the 112 tropical cyclones in the data set approached Yokohama. As the figure shows, almost 70% of the storms approached from the southwest. It should be noted that the approach direction is determined at CPA, and may not represent the initial approach direction of the tropical cyclone toward Yokohama.

Because of climatological considerations, there are preferred areas of the western North Pacific basin from which tropical cyclones eventually affect Yokohama. However, there are some tropical cyclones which, even though they traverse these preferred areas, do not affect Yokohama. Also, as might be expected, there are seasonal shifts to these preferred areas.

Figures V-204 through V-206 address the probability of tropical cyclones affecting Yokohama. Using a grid system, a tabulation was made of the total number of tropical cyclones passing through a given grid area regardless of whether they eventually passed within 180 nmi of Yokohama. A further tabulation was made of those storms which did eventually pass within that distance from Yokohama. After smoothing, the two tabulations were converted into probabilities and contours were drawn to connect points of equal probability.

The solid lines represent a "percent threat" for any tropical cyclone location within the area depicted. The heavy dashed lines represent the approximate time in days for a system to reach Yokohama. For example, as shown in Figure V-204, during the months of July and August a tropical cyclone located at 25°N 145°E has an approximate 40% probability of passing within 180 nmi of Yokohama and would reach Yokohama in about three to four days.

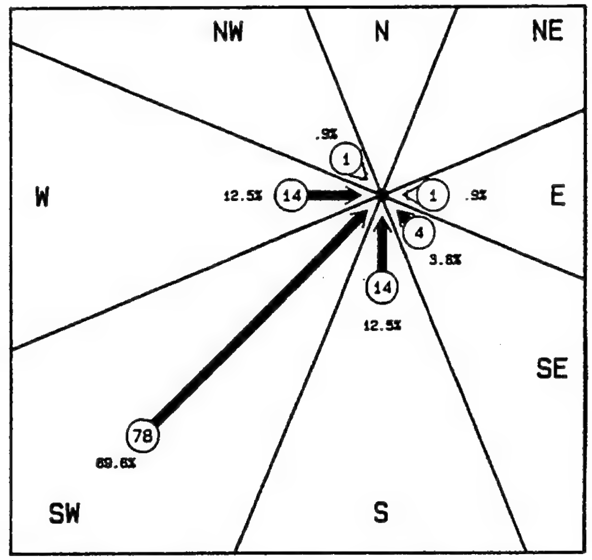

Figure V-203. Directions of approach for 112 tropical storms and typhoons passing within 180 nmi of Yokohama during the 48-year period 1945-1992. The length of each arrow is proportional to the number of storms from that direction.

The time-to-travel lines on Figures V-204 through V-206 represent average speed of advance (SOA) and are based only on those tropical cyclones that passed within 180 nmi of Yokohama. Because there are large variations in SOA at these latitudes, these average SOA's should only be used as general information. Planning actions for individual cyclones should be based on the current conditions and forecasts. Further, because most tropical cyclones that pass near Yokohama have recurved (SOA typically is slower during recurvature), the average SOA's reflected in the figures will likely be slower than the values that represent all of the tropical cyclones (non-recurvers and recurvers) passing through this region.

The average time-to-travel lines on each figure show that the speed of movement of tropical cyclones differs at different latitudes. For example, in Figure V-205 an average storm approaching within 180 nmi of Yokohama during September will travel about 360 nmi during the approximate two-day period when it is between 4½-6 and 3-4 days away from Yokohama and moving northwest along the primary threat axis. During the period when it is between 3-4 and 1½-2 days away, an average storm slows during recurvature and will travel about 300 nmi. However, when an average storm is less than 1½-2 days away, it begins to accelerate after recurvature and will travel about 700 nmi during that period. Figures V-204 and V-206 show similar changes in speed of movement for other months of the year. However, the early season storms shown in Figure V-204 exhibit a less dramatic increase in speed of movement in the last two days of travel.

A comparison of Figures V-204 through V-206 shows that there are significant differences in the threat axes depicted by the three figures. During the months of July and August (Figure V-204) the threat axis extends south from Yokohama to about 30°N before turning southeastward to a >40% maximum centered about 20°N 160°E. During the month of September (Figure V-205) the threat axis extends southwest from Yokohama to approximately 33°N, and then gradually turns southeastward to a >40% maximum centered about

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14°N 150°E. For the period of October through June (Figure V-206) the threat axis extends sharply southwestward from Yokohama to a position near 26°N 130°E before turning southeastward to lower latitudes.

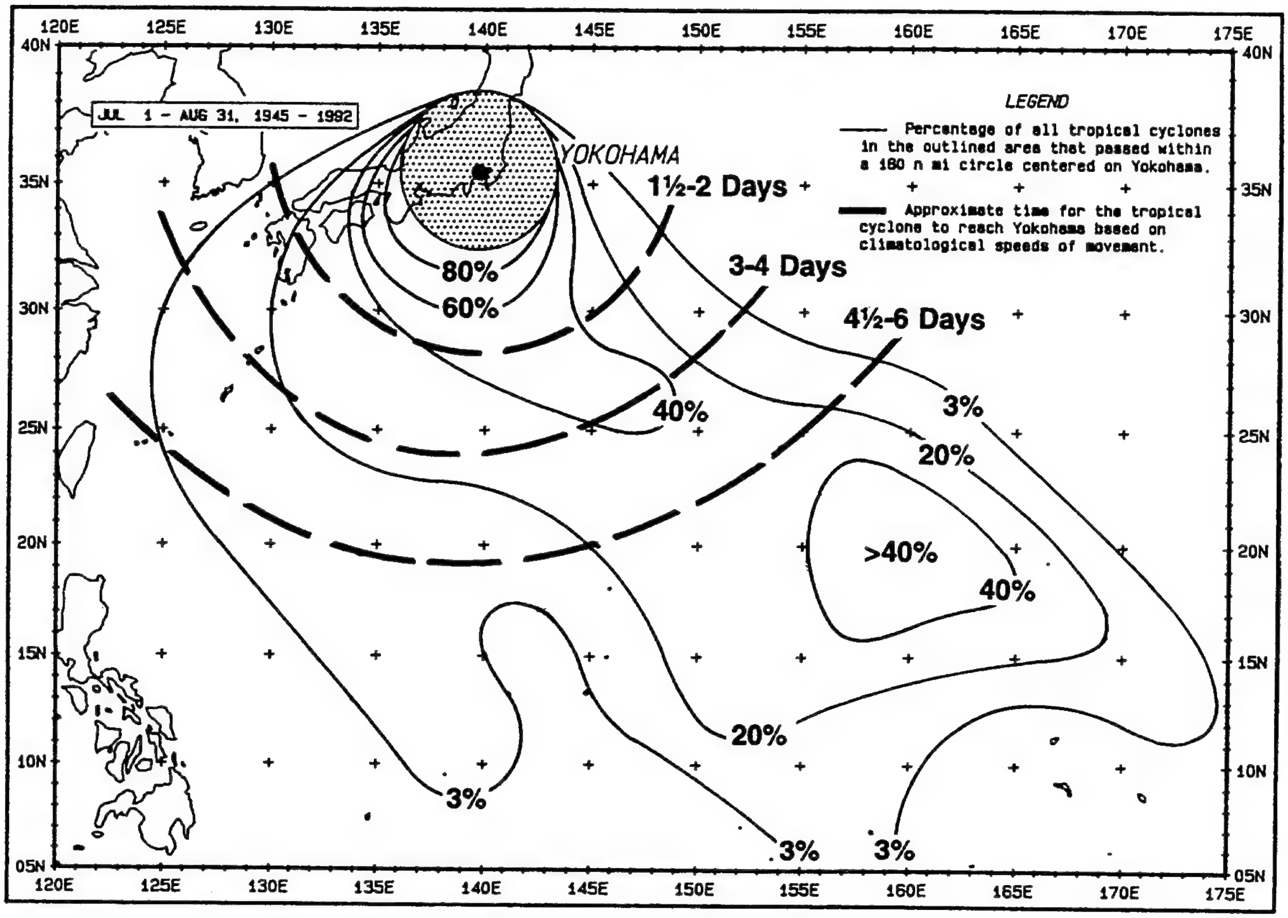

Figure V-204. Probability that a tropical storm or typhoon will pass within 180 nmi of Yokohama (circle), and approximate time to closest point of approach, during July and August.

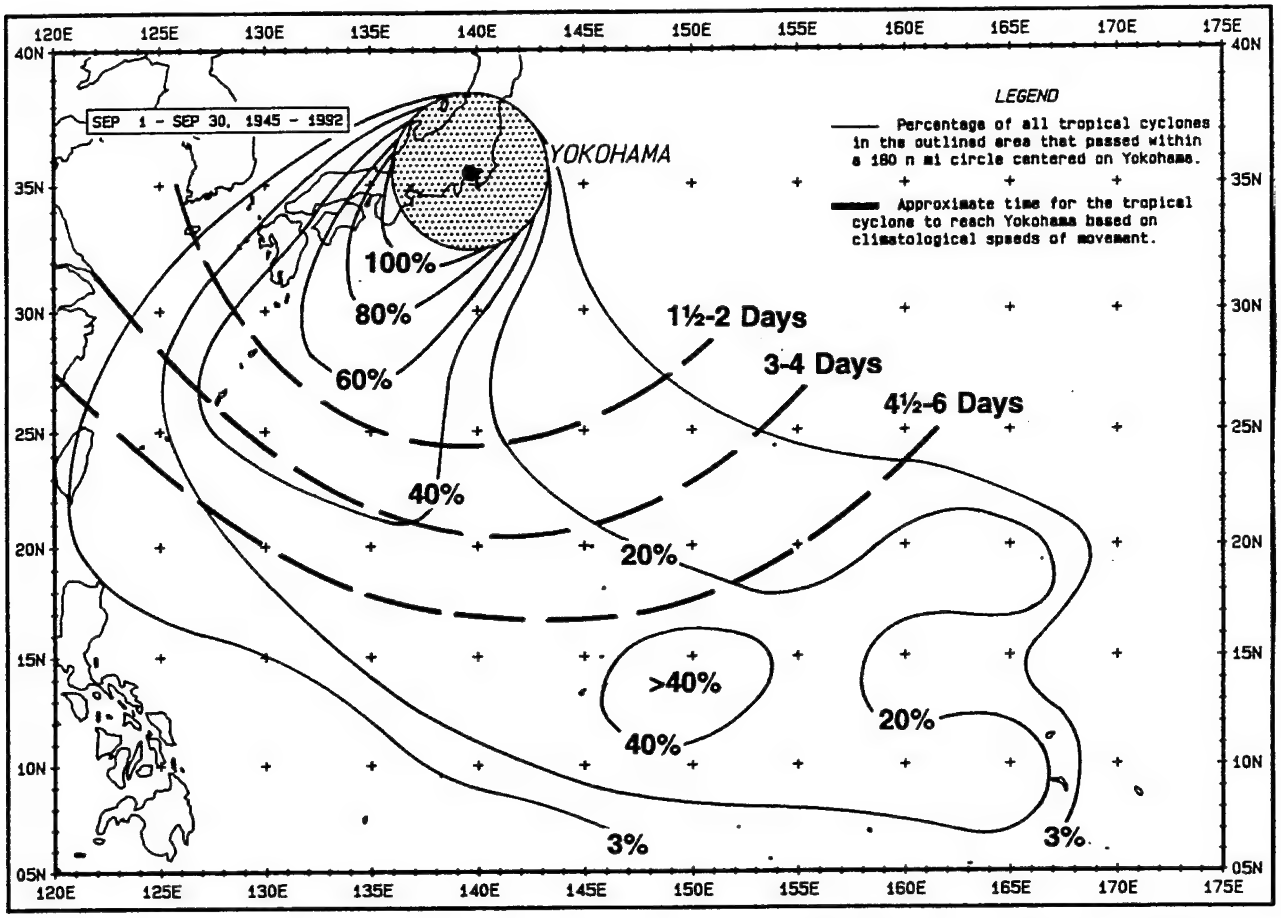

Figure V-205. Probability that a tropical storm or typhoon will pass within 180 nmi of Yokohama (circle), and approximate time to closest point of approach, during September.

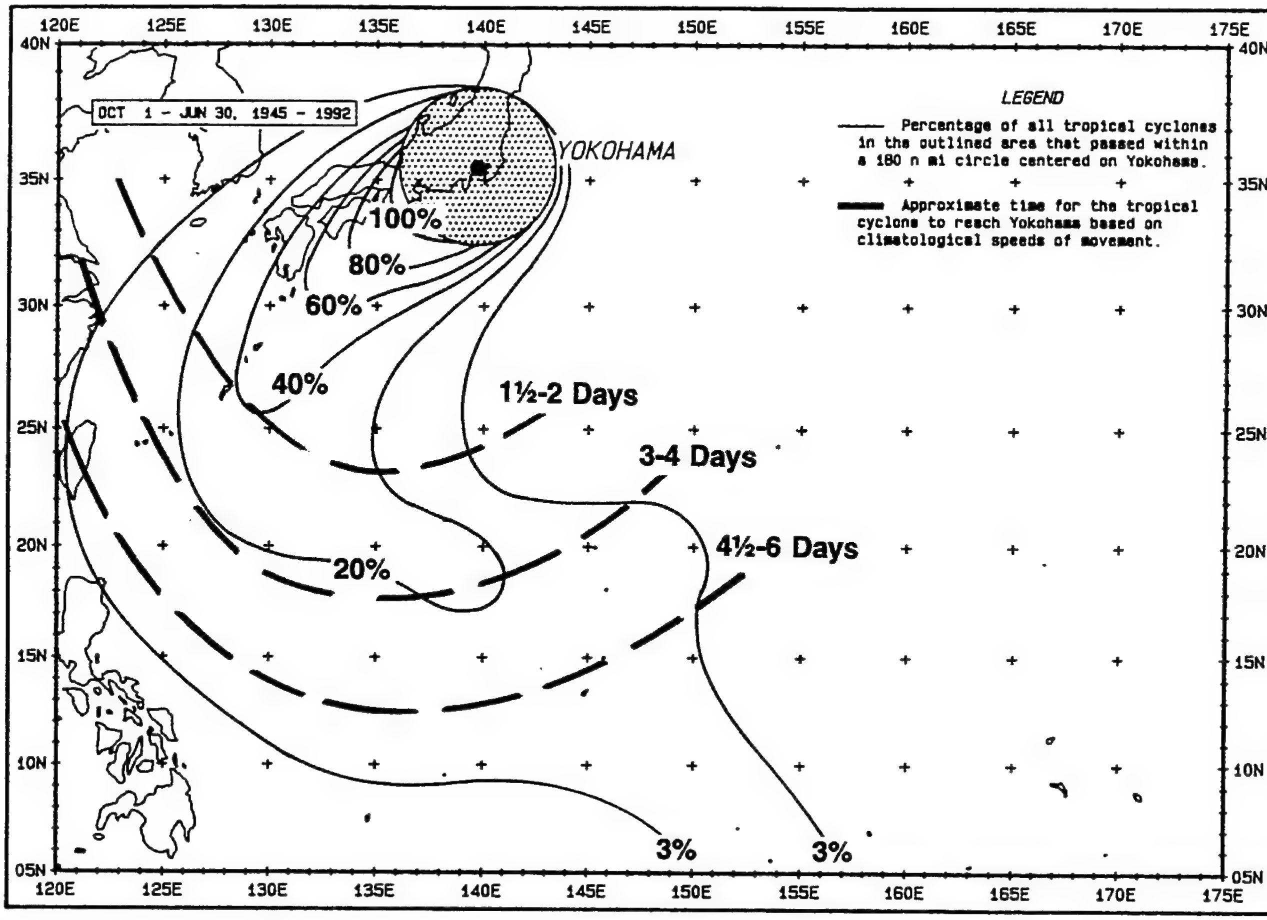

Figure V-206. Probability that a tropical storm or typhoon will pass within 180 nmi of Yokohama (circle), and approximate time to closest point of approach, during the period October through June.

15.5.2 Wind and Topographical Effects

Winds are measured for the Port of Yokohama at the Yokohama Regional Meteorological Station. It is located approximately 1.5 nmi south of the southeast end of Mizuho Wharf (Figure V-198). The ground elevation of the station is 128 ft (39 m) above sea level. The anemometer is located an additional 64 ft (19.6 m) above ground at the station, giving a total elevation of 192 ft (58.6 m) above sea level. Local port authorities state the measured winds are not influenced by buildings or terrain, and are representative of winds in the harbor. However, wind data contained in Table V-50 (Yokohama Regional meteorological Station) and Table V-51 (Tokyo International Airport) indicate that there may be a significant difference between the winds reported by the Meteorological Station and actual conditions experienced in more exposed areas of the harbor.

The data contained in Tables V-50 and V-51 have been selected from observations recorded during the passage of the tropical cyclones listed in each table.[1]

The wind and weather information listed in the tables include data from the Yokohama Regional Meteorological Station (35°26'N 139°39'E) for the 20-year period 1973 through 1992, and data from Tokyo International Airport (35°33'N 139°46'E) for the same period. As previously stated, the Yokohama site is located approximately 1.5 nmi south of the southeast end of Mizuho Wharf. Between 1985 and 1989 (exact date uncertain) the location of the Tokyo International Airport site changed to 35°33N 139°47E, a move of less than 1 nmi. The Tokyo International Airport sites are located just northeast of the port of Kawasaki, which places them approximately 7.5 to 8 nmi northeast of the southeast end of Mizuho Wharf (Figure V-198). From available charts, the more recent airport site appears to be situated on a low-lying, reclaimed portion of the bay. Station elevation at the airport sites changed from 6.6 ft (2 m) to 9.8 ft (3 m) in 1974, from 9.8 ft (3 m) to 19.7 ft (6 m) in 1981, and from 19.7 ft (6 m) to 26.3 ft (8 m) at some point between 1985 and 1989. Information on the elevation of the wind measuring equipment above ground level is not available.

Tables V-50 and V-51 contain observational data reported by the two sites during passages of selected tropical cyclones. An examination of the data contained in the tables reveals a significant difference in observed wind speeds at the two sites when data for the same passing storms are considered. In all cases, the winds reported by the Tokyo Airport are stronger than those reported by the Yokohama Regional Meteorological Station. The amount of the difference varies with each storm. On average, Tokyo International Airport's reported sustained winds are about 50% stronger than the sustained speeds reported by the Yokohama site. The majority of wind directions at the two sites are in close agreement.

The observed weather and maximum wind velocities listed in Tables V-50 and V-51 did not necessarily occur at the same time; the data in the tables represent the strongest wind and most severe weather conditions recorded during the entire passage of each storm. Wind gust data were not included in the Yokohama Regional Meteorological Station observations.

A total of 34 tropical storms or typhoons passed within 180 nmi of the Port of Yokohama during the period July 1973 through June 1992, the period during which surface observations for Yokohama are available. Of those storms, nine (26%) caused sustained winds of ≥22 kt at the Yokohama Regional Meteorological Station. Only one (3%), Typhoon Tip in 1979, caused winds of ≥34 kt. For the same period, however, 18 (53%) caused sustained winds of ≥22 kt at the Tokyo International Airport, and nine (26%) caused winds of ≥34 kt.

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[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

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Table V-50. Center data and related weather at the Yokohama Regional Meteorological Station associated with selected tropical cyclone passages within 180 nmi of Yokohama during the period 1973-1992. Reported weather is the most severe reported during the entire passage of storm and did not necessarily coincide with the strongest winds.

TROPICAL CYCLONE DATA				MOST SEVERE LOCAL CONDITIONS	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND (KT)	WEATHER
79/09/30 (OWEN)	043/47	331/88	43	S 23	MDT/HEAVY RAIN SHOWERS
79/10/19 (TIP)	046/61	310/68	60	SW 34	VIOLENT RAIN SHOWERS
80/10/14 (WYNNE)	066/39	167/91	70	N 18	VIOLENT RAIN SHOWERS
81/08/22 (THAD)	013/30	050/16	67	E 21	MDT/HEAVY RAIN SHOWERS
81/10/22 (GAY)	045/43	147/31	68	NNE 23	VIOLENT RAIN SHOWERS
82/09/12 (JUDY)	001/26	267/114	60	SSE 30	LIGHT RAIN SHOWERS
83/08/17 (ABBY)	068/12	300/16	45	SSE 20	MDT/HEAVY RAIN SHOWERS
85/06/30 (IRMA)	047/42	236/20	64	S 31	VIOLENT RAIN SHOWERS
89/08/27 (ROGER)	035/25	309/147	40	SW 22	LIGHT RAIN SHOWERS
89/09/19 (WAYNE)	062/41	144/33	58	N 18	VIOLENT RAIN SHOWERS
90/08/10 (WINONA)	037/18	317/30	58	SSE 26	MDT/HEAVY RAIN SHOWERS
90/09/19 (FLO)	035/33	306/113	63	SSW 27	THUNDERSTORM
91/09/14 (KINNA)	072/35	348/129	53	SW 22	NONE REPORTED
91/10/12 (ORCHID)	058/17	147/176	55	N 23	LIGHT RAIN SHOWERS

Table V-51. Center data and related weather at Tokyo International Airport associated with selected tropical cyclone passages within 180 nmi of Yokohama 1973-1992. Direction and CPA data are in reference to Yokohama site. Reported weather is the most severe reported during the entire passage of storm and did not necessarily coincide with the strongest winds.

TROPICAL CYCLONE DATA				MOST SEVERE LOCAL CONDITIONS	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	WEATHER
79/09/30 (OWEN)	043/47	331/88	43	S 37G49	MDT/HEAVY RAIN SHOWERS
79/10/19 (TIP)	046/61	310/68	60	S 47G77	THUNDERSTORM
80/10/14 (WYNNE)	066/39	167/91	70	N 30G45	THUNDERSTORM
81/08/22 (THAD)	013/30	050/16	67	E 34G50	VIOLENT RAIN SHOWERS
81/10/22 (GAY)	045/43	147/31	68	NNE 40G57	HEAVY RAIN
82/08/01 (BESS)	360/34	278/127	53	SSE 49G73	VIOLENT RAIN SHOWERS
82/09/12 (JUDY)	001/26	267/114	60	S 42G60	LIGHT RAIN SHOWERS
83/08/17 (ABBY)	068/12	300/16	45	SSE 27G42	MDT/HEAVY RAIN SHOWERS
85/06/30 (IRMA)	047/42	236/20	64	S 47G72	VIOLENT RAIN SHOWERS
85/08/30 (RUBY)	015/14	114/8	45	NE 34G46	VIOLENT RAIN SHOWERS
89/08/27 (ROGER)	035/25	309/147	40	S 32G49	VIOLENT RAIN SHOWERS
89/09/19 (WAYNE)	062/41	144/33	58	N 26G43	THUNDERSTORM

Seven of the nine storms causing sustained ≥22 kt winds at the Yokohama Regional Meteorological Station passed west of the harbor; two storms passed east. Typhoon Tip was the only storm bringing ≥34 kt winds to the station, and Tip passed west of the port. Of the 18 storms bringing sustained

≥22 kt winds to Tokyo International Airport, ten passed west of Yokohama, and eight passed to the east. Of the nine storms causing winds of ≥34 kt at the airport, six passed west of Yokohama and three passed to the east.

In the harbor, the direction of the resultant wind is the basic difference between a storm passing east of the harbor and one passing to the west. If the tropical cyclone passes west of Yokohama, the wind will generally be from the south. An example of this was Typhoon Tip (October 1979) which had a CPA of 68 nmi northwest of Yokohama. Tip caused southerly winds of 47 kt with gusts to 77 kt at Tokyo International Airport and 34 kt at the Yokohama Regional Meteorological Station.

If the tropical cyclone passes east of Yokohama, the path will be over water and the wind in the harbor will be generally northerly. An example of this was Typhoon Gay in October 1981. Gay brought north-northeasterly winds of 40 kt with gusts to 57 kt to Tokyo International Airport while the Yokohama Regional Meteorological Station recorded 23 kt.

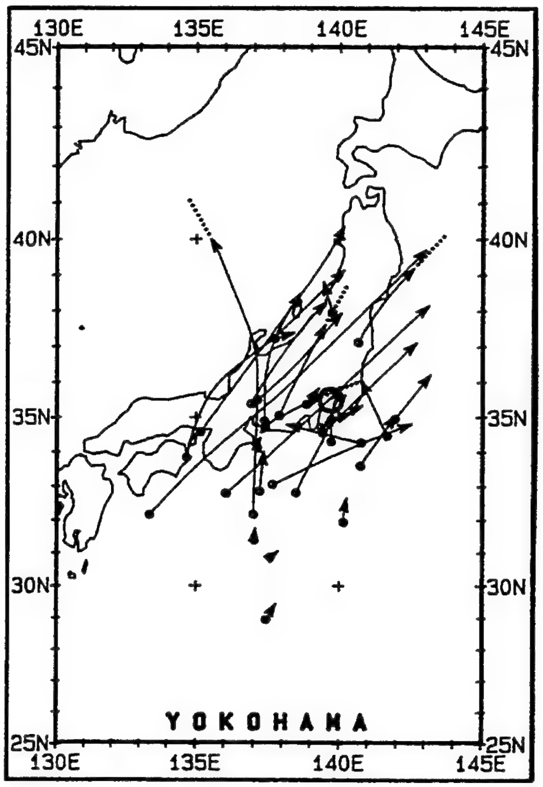

Figure V-207. Track segments of the 23 tropical storms or typhoons causing sustained winds of at least 22 kt at Yokohama or Tokyo International Airport during the 20-year period 1973-1992. Dots at the end of a track indicate that ≥22 kt winds continued beyond the end of the track segment shown.

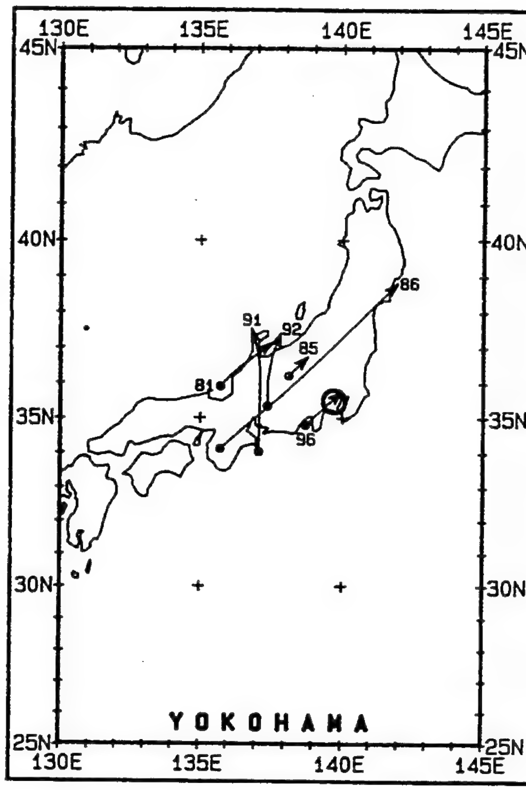

Figure V-208. Track segments of the six tropical storms or typhoons causing sustained winds of at least 34 kt at Yokohama or Tokyo International Airport during the 20-year period 1973-1992. The numbers shown correspond to the index numbers listed in Table V-48.

The beginning and end points of the arrows in Figure V-207 give the positions of 23 tropical cyclone centers when sustained winds of ≥22 kt began and ended at Yokohama or Tokyo International Airport. Eleven of the 34 storms that passed within 180 nmi during the period 1973 through 1992 did not cause winds of ≥22 kt. Winds ≥22 kt began (and, incidentally, ended) in only three instances when the storm center was south of 32°N.

Figure V-208 shows the positions of six tropical cyclone centers when sustained winds of ≥34 kt began and ended at Yokohama or Tokyo International Airport. None of the winds ≥34 kt began before the storm center was north of 34°N.

15.5.3 Waves

The configuration of Tokyo Bay (Figure V-197) provides excellent protection to the Port of Yokohama from ocean swells. Miura Peninsula on the west side of the bay, and narrow Futtsu Point, which extends westward from the Boso Peninsula on the east side of the bay, prevent significant open-ocean wave motion from reaching Yokohama. Interviews with local harbor authorities reveal that, under 30 kt (15 m s^{-1}) wind conditions, waves are limited to about 3.3 ft (1 m) within the harbor and 6.6 ft (2 m) in the anchorages.

The Guide to the Port of Yokohama, published by the Port of Yokohama Promotion Association in 1992, provides the following generalities regarding waves at Yokohama.

> Under normal weather conditions, waves observed by the Yokohama District Weather Bureau are most frequently 1 ft to 1.6 ft (0.3 m to 0.5 m) high with a wind velocity of over 10 kt (5 m s^{-1}). The annual occurrence of waves higher than 1.6 ft (0.5 m) is about 17 percent, while those exceeding 4.6 ft (1.4 m) are rarely observed. However, because this observation is related to only one-third of the wave heights observed, there is the possibility that waves exist with maximum heights which are 60-80 percent higher.
>
> Under abnormal weather conditions, such as typhoon passages, waves have been observed on different occasions as follows: 10.5 ft (3.19 m), 10.5 ft (3.19 m), 8.5 ft (2.6 m), 7.2 ft (2.2 m) and 8.5 ft (2.6 m). The highest wave mentioned, 10.5 ft (3.19 m), occurred during Typhoon "Isewan," year not specified. The document goes on to state "The maximum height of waves during this typhoon was 60-80 percent higher than the average height under normal weather conditions. It is therefore possible for waves" 18 ft - 19.7 ft (5.5 m - 6.0 m) high "to occur once every 10-20 minutes, although this would not occur continuously."
>
> Regarding the impact of ocean swell impacting the harbor, the document further states: "Even when there are 10-meter-high swells in the Pacific, they are only 10 cm high in the harbor, which is nearly insignificant."

YOKOHAMA

15.5.4 Storm Surge

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. Storm surge is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. The piling up of water on a coast ahead of a tropical storm or typhoon is more apparent in the dangerous semicircle, the region of most intense winds. The Port of Yokohama will be placed in the dangerous semicircle when a typhoon passes west of the area.

The storm surge effect is most evident in the shallow waters of large inland bays open to the south coast of Japan (Miyazaki, 1974). To a large extent, the surge forms after entering the inland bays because the width of the continental shelf is generally narrow along the Japanese coast. Most of the surge occurs, therefore, at the inshore end of these bays, and not along the open coasts nor near the mouth of the bays. Because Tokyo Bay is open to the south, a wind with a strong southerly component is necessary to cause a storm surge in the bay.

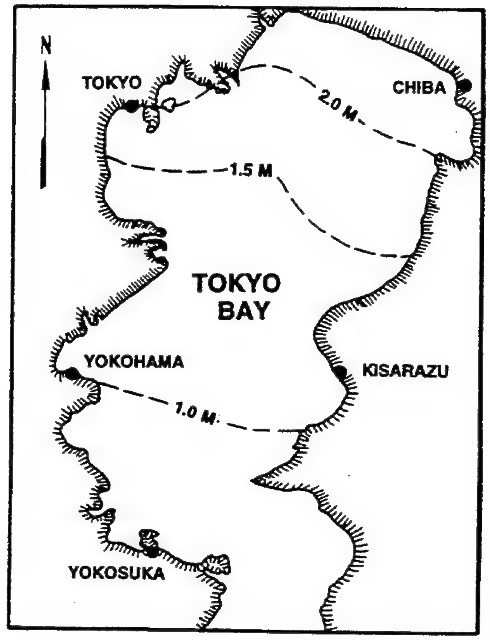

Figure V-209. Relative storm surge heights for Tokyo Bay. Adapted from Meteorological and Oceanographic Characteristics for Safe Navigation of Ships on Tokyo Bay and Surrounding Waters.

Local authorities state that the highest storm surge experienced at the Port of Yokohama is 10.67 ft (3.25 m), which occurred in October 1959. Because mean sea level at Yokohama is 3.77 ft (1.15 m) above the standard sea level height of zero, the value would translate to a water rise above mean sea level of 6.9 ft (2.1 m).

As shown in Table V-52, a storm surge height of 4.63 ft (1.41 m) was observed at Tokyo during the passage of Typhoon Kitty on August 31, 1949. A graph included in the document entitled Meteorological and Oceanographic Characteristics for Safe Navigation of Ships on Tokyo Bay and Surrounding Waters that was published by the Tokyo Bay Marine Disaster Prevention Organization in 1993 compares the surge heights at Tokyo and Yokohama during Kitty's passage. The graph shows that Yokohama's maximum surge height was approximately 22% less than Tokyo's maximum surge height. As Tokyo is located farther north in Tokyo Bay than Yokohama, it is to be expected that Tokyo would likely experience somewhat higher surge values (Figure V-209). The average percentage difference between the two locations for all storm surges is not known.

Figure V-209 has been adapted from the document referenced in the preceding paragraph and depicts the approximate relative difference in surge heights within the confines of Tokyo Bay. It shows that the greatest surge heights occur in the northern part of the bay.

Table V-52. Past occurrences of storm surge level extremes at Tokyo, 10 nmi northeast of Yokohama in the north part of Tokyo Bay (adapted from Tokyo Bay Marine Disaster Preventative Organization, 1993).

DATE (STORM NAME IF KNOWN)	SURGE HEIGHT ABOVE AVERAGE WATER LEVEL (FEET)/(METERS)	MINIMUM PRESSURE (MB)	MAXIMUM WIND (KT)/(M S^{-1})
JULY 26, 1911	6.82/2.08	970.2	SSE 61/31.4
OCT. 1, 1917	7.55/2.30	952.7	SSE 77/39.6
SEP. 1, 1938	6.36/1.94	978.6	S 60/31.0
AUG. 31, 1949 (KITTY)	4.63/1.41	986.1	SE 48/24.9
JULY 23, 1958 (ALICE)	3.71/1.13	986.1	S 44/22.8
SEP. 26, 1959 (VERA)	3.38/1.03	989.4	S 52/27.0

Notes provided by a representative of the Japanese Meteorological Agency contain the following equations. They are used to forecast the amount of storm surge at Yokohama during the passage of a tropical cyclone.

Water rise caused by wind speed:

$$A1 = 0.16V^2$$

Where: $A1$ = amount of water rise (cm)
V = wind speed in m s^{-1}

Example: Wind speed of 30 m s^{-1}
$30^2 = 900$

$$\begin{array}{r} 900 \\ \times\ \underline{0.16} \\ 144 \end{array}$$
144 cm (4.72 ft) water rise.

Water rise caused by atmospheric pressure decrease:

$$A2 = 1010\text{-}P$$

Where: $A2$ = amount of rise (cm)
P = Pressure (mb or hPa)

Example: 960 mb pressure

$$\begin{array}{r} 1010 \\ \underline{-960} \\ 50 \end{array}$$
50 cm (1.64 ft) water rise.

When the preceding equations are applied to the six examples listed in Table V-52, the results closely approximate the actual water rise in all but two cases. In those two cases, October 1, 1917 and September 26, 1959, the calculated rise exceeded each observed value by about 34%. Calculations for the four remaining cases were lower than the observed values by 5% to 13%.

The following table, adapted from Tokyo Bay Marine Disaster Prevention Organization (1993), lists the probabilities of occurrence of storm surges of the heights listed. It should be noted that the data are for Tokyo rather than Yokohama.

Table V-53. Intervals between storm surge heights of specified values for Tokyo (Tokyo Bay Marine Disaster Prevention Organization, 1993).

SURGE HEIGHT	1.6 FEET/ 0.5 METER	3.3 FEET/ 1.0 METER	4.9 FEET/ 1.5 METERS	6.6 FEET/ 2.0 METERS
INTERVAL BETWEEN OCCURRENCES	1 YEAR	8 YEARS	23 YEARS	35 YEARS

15.6 THE DECISION TO EVADE OR REMAIN IN PORT

15.6.1 General

Local harbor authorities at Yokohama state that U. S. Navy ships at Yokohama should move to Fleet Activities, Yokosuka in the event of a threat by a tropical cyclone. Ships moored to Mizuho Wharf at Yokohama will likely be under the operational control of the Military Sealift Command, Far East. The responsibility for overall coordination of action to be taken by Naval activities in the Yokosuka area has been assigned to Commander, Fleet Activities, Yokosuka. SOPA (ADMIN) YOKOSUKA INSTRUCTION 5000.1 establishes procedures when hazardous weather is expected at Yokosuka, and the same instruction is applicable to Military Sealift Command vessels at Yokohama. The Naval Pacific Meteorology and Oceanography Facility (NPMOF), Yokosuka issues local wind warnings. As directed by SOPA, wind from any direction with expected sustained speeds of 48 kt or gusts in excess of 55 kt is sufficient to set tropical cyclone Conditions of Readiness (COR). Modified COR's may be set for different areas if wind velocities are expected to differ between different sites within the area of responsibility of Commander, Fleet Activities, Yokosuka. Typhoon conditions will be set for an approaching typhoon, i.e., expected sustained winds of 64 kt or greater. The same precautions taken for a typhoon will be taken for any tropical cyclone.

For general information on tropical cyclone warnings, refer to Chapter I.

15.6.2 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. A basic understanding of weather and proper utilization of meteorological products, especially the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/ JTWC) Guam Tropical Cyclone Warnings, will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures V-204 through V-206, discussed earlier, address the probability of existing remotely located tropical cyclones later affecting Yokohama. Figures V-210 through V-212 have been prepared as additional aids for the commander to use when evaluating a given situation. In contrast to Figures V-204 through V-206, Figures V-210 through V-212 consider only those storms which later passed within 180 nmi of Yokohama. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered as an average approach scenario insofar as Yokohama is concerned. It must be stressed that the other 50% of the storms which later affect Yokohama will be outside of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures V-210 through V-212.

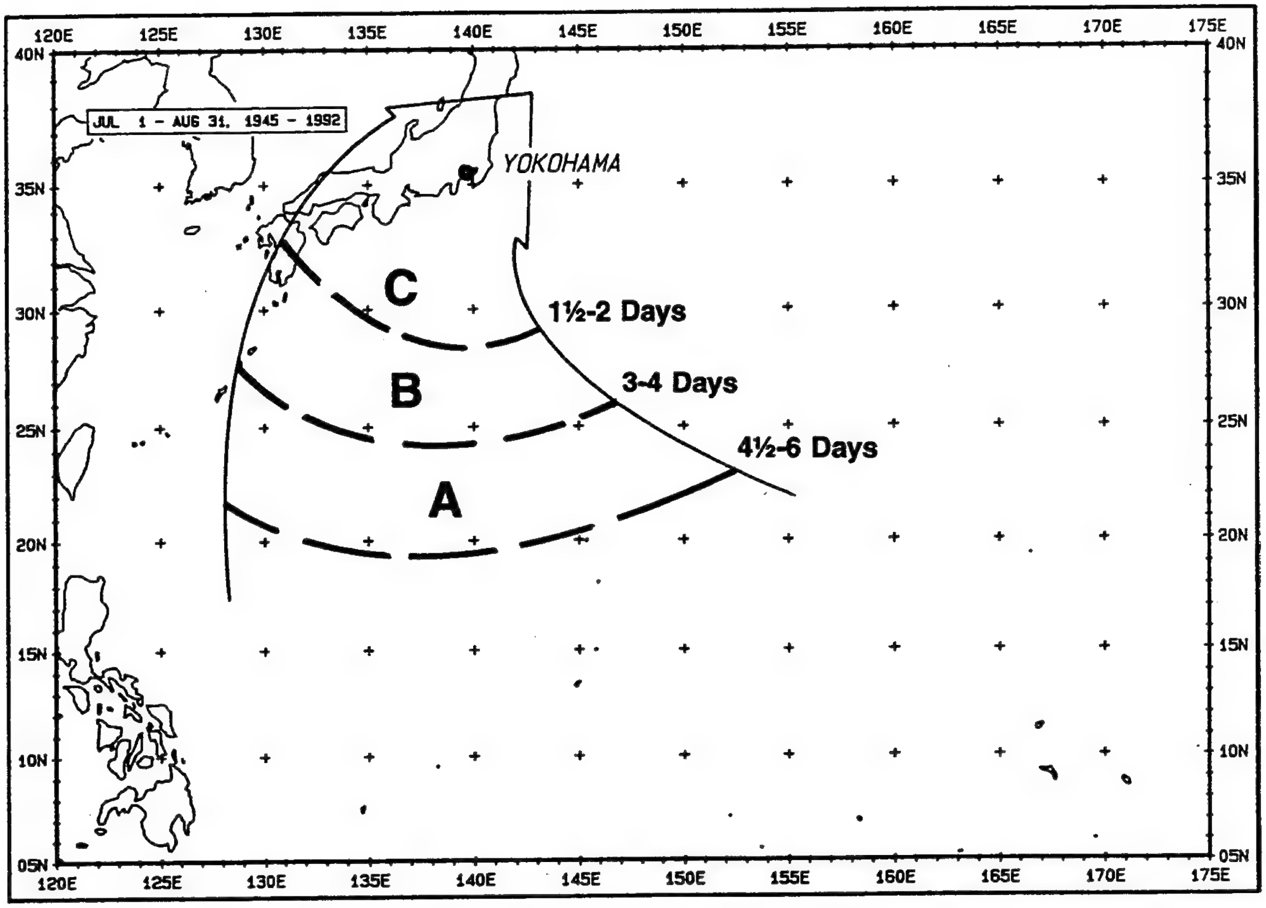

Figure V-210. For the tropical cyclones passing within 180 nmi of Yokohama during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Yokohama. See Figure V-204 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Yokohama.

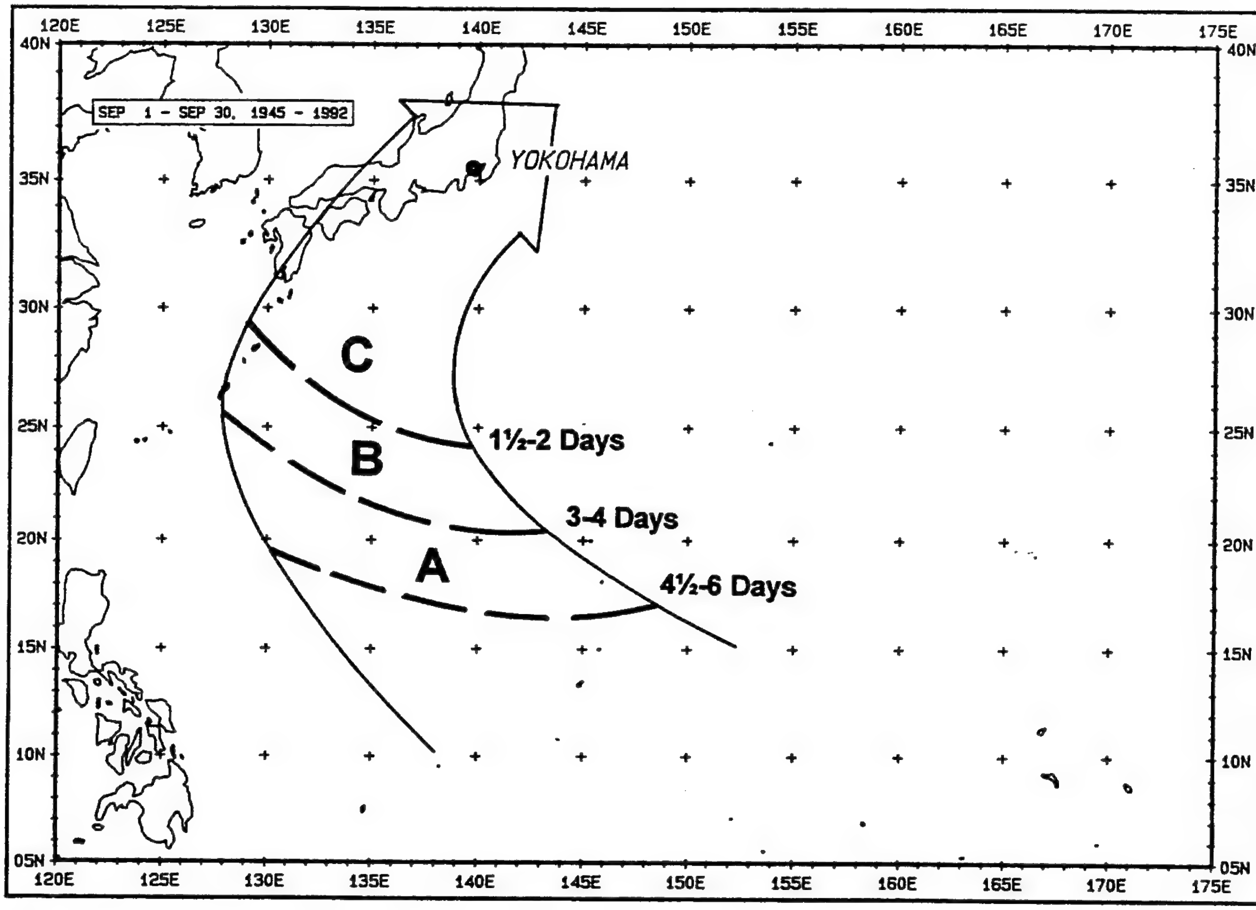

Figure V-211. For the tropical cyclones passing within 180 nmi of Yokohama during September, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Yokohama. See Figure V-205 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Yokohama.

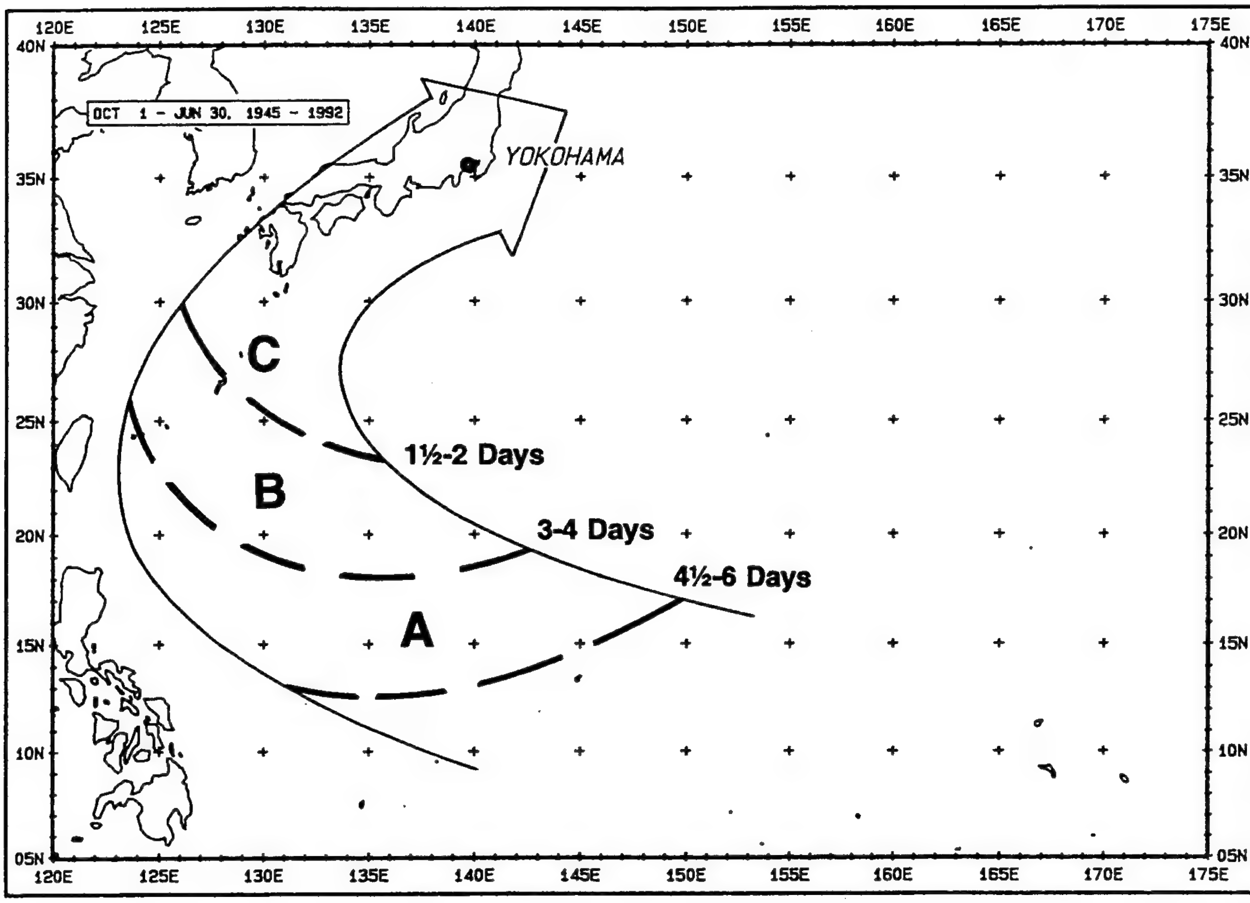

Figure V-212. For the tropical cyclones passing within 180 nmi of Yokohama during the period October through June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Yokohama. See Figure V-206 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Yokohama.

With the above restrictions in mind, the following time/action sequence, to be used in conjunction with Figures V-210 through V-212, has been prepared to aid in these actions.

I. An existing tropical cyclone moves into or development takes place in Area A with long range forecast movement toward Yokohama (recall that 40% of all tropical cyclones recurve):

a. Review material condition of ship.

b. Reconsider any maintenance that would render the ship incapable of riding out a tropical storm or typhoon with the electrical load on ship's power, or would render the ship incapable of getting underway, if need be, within 48 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters Area B with forecast movement toward Yokohama (recall that prior to recurvature, tropical cyclones tend to slow in their forward motion and accelerate rapidly after recurvature):

a. Reconsider any maintenance that would render the ship incapable of going to anchor, moving to Fleet Activities, Yokosuka, or sortieing from the port.

b. Consider all options available to the ship if the tropical cyclone continues to approach Yokohama. Review Yokosuka's evaluation in Section V.2 of this manual.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone has entered Area C and is moving toward the Yokohama area:

a. Prepare to leave Mizuho or Shinko Wharf.

1. If moving to Yokosuka, the transit (including berthing at Fleet Activities) should be completed before the predicted onset of 20 kt winds. Anticipate Tropical Cyclone Conditions II and I or Modified Tropical Cyclone conditions II and I to be set by SOPA Yokosuka. Take appropriate actions.

2. If remaining at Yokohama, shifting from alongside moorage to the anchorage is required if winds are forecast to reach 30 kt (15 m s^{-1}).

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

15.6.3 Remaining in Port

Remaining alongside Mizuho Wharf at the Port of Yokohama is not recommended and, according to local harbor authorities, is not an option. As stated in Section 15.6.2 above, ships should leave their berths and move to the Nakano Se anchorage if the wind is forecast to reach or exceed 30 kt (15 m s^{-1}). Ships remaining in the anchorage during passage of a tropical cyclone should be prepared for waves of 6.6 ft (2 m) or higher, and steam to the anchor during the passage of the storm to reduce strain on the anchor chain and lessen the possibility of anchor dragging.

Instead of remaining in port at Yokohama, the ship's captain may elect to move to Fleet Activities, Yokosuka to ride out the storm. This option is, of course, dependent on the availability of appropriate berthing or anchoring space at Yokosuka. An early decision is mandatory. Harbor authorities at Yokosuka state that the large number of Japanese fishing boats that move into Yokosuka Bay for shelter prior to typhoon passage

severely restricts the ability of larger vessels to enter or leave the port. A summary of port facilities and typhoon procedures for Fleet Activities, Yokosuka is contained in Section V.2 of this manual.

15.6.4 Evasion in Tokyo Bay

All vessels will need to make an early decision if a departure from the harbor is being considered. Boat traffic within Tokyo Bay is heavy prior to the arrival of a tropical cyclone as small craft seek sheltered positions.

Japanese Maritime Self Defense Force (JMSDF) ships use Tatayama Bay and Kisarazu Harbor (Figure V-197) as anchorages when a typhoon is expected to pass east of Tokyo Bay. Water depths in Tatayama Bay are deep enough for vessels of all sizes and the bottom offers good holding.

Merchant vessels have at times, depending on the direction of the tropical storm or typhoon CPA, anchored in the following areas identified in Figure V-197:

(1) Tropical cyclone passage to the east or south of Tokyo Bay: anchor in Chiba Harbor or Kisarazu Harbor.

(2) Tropical cyclone passage to the west or north of Tokyo Bay: anchor in Kaneda Bay.

The 3rd Regional Maritime Safety headquarters has issued a brochure titled INFORMATION SERVICE FOR VESSELS AT ANCHOR IN TOKYO BAY IN THE EVENT OF A TYPHOON APPROACHING THE MAIN ISLAND OF HONSHU, dated June, 1992. The following information has been excerpted from the brochure.

> During the period when typhoons are approaching the main island of Honshu, Tokyo Bay anchorages tend to become overcrowded with vessels seeking shelter from the approaching bad weather. Overcrowding of anchorages during stormy weather can lead to the additional hazards of collisions and grounding due to anchor dragging. To prevent and reduce the risk of such accidents, the Tokyo Bay Traffic Advisory Service Center (Call sign TOKYO MARTIS) provides information services for vessels at anchor or seeking anchorage in Tokyo Bay. The center airs information services broadcasts following advisory warnings to evacuate the port or harbor due to an approaching typhoon.
>
> Broadcasts will be in Japanese on the hour and half hour, on a frequency of 1665 kHz, and contain information on the number of vessels anchored in each of the following areas:

1.	Off Kurihama	2.	Off Yokosuka
3.	Off Yokohama	4.	Off Kawasaki
5.	Off Tokyo	6.	Off Funabashi
7.	Off Chiba	8.	Off Banzu-Hana
9.	Off Kisarazu	10.	Off Futtu
11.	Off Sasage	12.	Nakano Se

The brochure also makes the following recommendations to be taken during stormy weather:

(1) Maintain a listening watch on VHF Channel 16 or by radio on 1665 kHz.

(2) Listen for warnings on vessels which are dragging their anchors. The warnings will be broadcast on VHF Channel 12 following a general call on Channel 16.

(3) Keep a proper watch with sufficient lookouts. If necessary, main engines should be ready for immediate use. Power to windlasses should also be available for emergency use.

(4) Maintain a safe distance from other vessels and be alert for signs of anchor dragging either by your own vessel or others in the vicinity. Be aware that a sudden change of wind speed and direction may affect anchor holding power.

(5) Take into account the depth of water and type of holding ground in the anchorage and, if necessary, use both anchors with sufficient scope of cable laid out. Main engines should be used to back-up the anchors if necessary.

(6) Improve the vessels sea-keeping qualities at anchor in order to reduce the risk of anchor(s) dragging. For example, vessels with large sail areas should consider measures such as taking on additional ballast, altering the vessel's trim, and use of main engines to prevent the vessel from dragging her anchor.

Vessels carrying a dangerous cargo must anchor as directed by the Japanese Maritime Safety Office. Ships requiring a pilot to transit the Uraga Suido Traffic Route may be unable to secure pilot services if winds are greater than about 35 kt because pilots embark and debark from small motor launches.

15.6.5 Evasion at Sea

Evasion routes at sea may be developed by the use of the tropical cyclone warnings (see Chapter I) and Appendix A for the month of interest in conjunction with Figures V-204 to V-206 (tropical cyclone threat axes and approach times to Yokohama). In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion route.

If the decision is made to evade at sea, the captain should plan to get underway days in advance of the storm's arrival. It must be remembered that tropical cyclones are notoriously difficult to accurately forecast, especially in the recurvature phase. The 48-hour forecast position error may exceed 200 nmi. A storm may be closer to or farther from Yokohama than the forecast indicates, or right or left of the storm's forecast track.

A late departure from port may make the sortie difficult due to fishing boat congestion and would increase the likelihood of encountering heavy weather as the ship departs Tokyo Bay. Each tropical storm or typhoon must be considered as differing from those preceding it. The existing synoptic situation must be fully understood. To blindly establish and follow one technique or rule for avoiding the storm's danger area is not practical, and may place the ship in harm's way.

In general, a departing ship, upon entering the area of Kannon Saki (Figure V-197), will begin to feel the effects of wave/swell generated by a tropical cyclone. The waves may reduce the ship's speed of advance (SOA), thereby increasing the time required to reach open sea. If a ship is caught in the wave/swell pattern ahead of a tropical cyclone, particularly an intense tropical storm or typhoon, the SOA may be reduced to the point that the ship will be unable to maneuver to clear the danger area (see Figure I-1). If the typhoon is forecast to follow a recurving track, with a CPA east of Yokohama, then a course downsea/downwind in the left (so-called navigable) semicircle may be considered. Extreme caution is advised, however, due to the possibility that the storm may not recurve as forecast, and the ship may be placed in the dangerous semicircle of the storm's circulation.

Any course to the north along the east coast of Honshu is considered unwise. The possibility of being overrun exists if the storm accelerates and/or turns suddenly to the north. The average speed of advance in the higher latitudes (30°N to 40°N) of tropical cyclones is about 25 kt; however, they have been tracked as fast as 60 kt (see Table V-48, Typhoon Tip in October 1979), and speeds of ≥40 kt are not uncommon. Typhoon wind intensities tend to decrease as the system moves into the northern latitudes, but nevertheless remain strong enough to be quite destructive.

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with Mr. Akinori Noda, Chief, Yokohama Maritime Safety Office and Captain of the Port; Mr. Kaneda Kishio, Assistant Chief, Marine Affairs Division, Port and Harbor Bureau, Yokohama City Government; Mr. Yoshiaki Yano, Research Officer, Disaster Preventive Section, Yokohama Regional Meteorological Station of the Japanese Meteorological Agency; Mr. Hisau Tsukamoto, Division Head, 2nd Sea Duty Division, Safety Navigation Section, Yokohama Maritime Safety Department; and Mr. N. Kagaya of the Yokohama Maritime Safety Office to obtain much of the information contained in this port evaluation.

REFERENCES

Miyazaki, M., 1974: Characteristics of Storm Surges Induced by Typhoons Along the Japanese Coast. Meteorological Research Institute, Tokyo, Japan.

Port of Yokohama Promotion Association, 1992: Guide to the Port of Yokohama.

The 3rd Regional Maritime Safety Headquarters, 1992: INFORMATION SERVICE FOR VESSELS AT ANCHOR IN TOKYO BAY IN THE EVENT OF A TYPHOON APPROACHING THE MAIN ISLAND OF HONSHU.

Tokyo Bay Marine Disaster Prevention Organization, 1993: Meteorological and Oceanographic Characteristics for Safe Navigation of Ships on Tokyo Bay and Surrounding Waters. Change (unnumbered).

REFERENCES

INSTRUCTIONS/NOTICES

Commander in Chief, U.S. Pacific Fleet
CINCPACFLT OPORD 201-(YR) Annex H

Commander in Chief, U.S. Seventh Fleet
COMSEVENTHFLT OPORD 201-(YR) Annex H

Commander, U.S. Naval Forces Japan
COMNAVFORJAPANINST 3140.1 (series)

Commander, U.S. Fleet Activities, Yokosuka
COMFLEACTINST 3140.1 (TROPICAL CYCLONE PLAN)
COMFLEACTINST 5000.1 (SOPA ADMIN)

Commander, U.S. Fleet Activities, Okinawa
COMFLEACTINST 5000.1 (SOPA OKINAWA)

Commander, U.S. Naval Forces, Sasebo
COMFLEACTINST 5000.1 (SOPA ADMIN)

GENERAL LITERATURE

Burroughs, L.D, and S. Brand, 1972: Speed of Tropical Storms and Typhoons After Recurvature in the Western North Pacific Ocean. ENVPREDRSCHFAC Technical Paper No. 7-72.

Chin, P.C., 1972: Tropical Cyclone Climatology for the China Seas and Western Pacific from 1884 to 1970. Hong Kong Royal Observatory.

Commander in Chief, U.S. Pacific Fleet, 1974: Port Directory, Vol. V, Pacific Ocean.

Crutcher, H.L. and R.G. Quayle, 1974: Mariners Worldwide Climatic Guide to Tropical Storms at Sea. NAVAIR 50-1C-61.

FICPAC, 1987: Port Directory for Hachinohe, Japan. Change 6. Joint Intelligence Center, Pacific, Pearl Harbor, HI.

REFERENCES

GENERAL LITERATURE (con't)

Gidley, R.E., 1967: Iwakuni Forecasters Handbook, AOW: 3145.2. Weather Service, U.S. Marine Corps Air Station, Iwakuni, Japan.

Graff, R.J., 1975: An Evaluation of the Harbor of Yokosuka, Japan as a Typhoon Haven. ENVPREDRSCHFAC Technical Paper No. 15-75.

Manning, J.R., 1975: An Evaluation of the Harbors of Iwakuni and Kure, Japan as Typhoon Havens. NAVENVPREDRSCHFAC Technical Paper No. 23-75.

Miyazaki, M., 1974: Characteristics of Storm Surges Induced by Typhoons Along the Japanese Coast. Meteorological Research Institute, Tokyo, Japan.

Rudolph, D. K., 1975: An Evaluation of Sasebo Harbor, Japan as a Typhoon Haven. ENVPREDRSCHFAC Technical Paper No. 6-74.

Rudolph, D. K., F.J. Blake, S. Brand and J. Blelloch, 1975: An Evaluation of the Harbors of Buckner Bay and Naha, Okinawa as Typhoon Havens. NAVENVPREDRSCHFAC Technical Paper No. 21-75.

Somervell, W.L. and J.D. Jarrell, 1970: Tropical Cyclone Evasion Planning. NAVWEARSCHFAC Technical Paper No. 16-69 (Rev.)

The Third Regional Maritime Safety Headquarters, 1992: Information service for vessels at anchor in Tokyo Bay in the event of a typhoon approaching the main island of Honshu.

Wixom, R.F., 1975: An evaluation of the Numazu Operating Area and Kagoshima Harbor as typhoon havens. NAVENVPREDRSCHFAC Technical Paper No. 24-75.

U.S. Army Coastal Engineering Research Center, 1973: Shore protection manual (Vol I). Dept. of the Army Corps of Engineers.

U.S. Fleet Weather Central/Joint Typhoon Warning Center: Annual Typhoon Reports. Guam, Marianas, 1961 through 1992.

GENERAL LITERATURE (con't)

U.S. Hydrographic Office, 1967: Danger areas in the Pacific (4th Ed.). H.O. Pub. 110.

U.S. Hydrographic Office, 1969: Fleet guide to Tokyo Wan. H.O. Pub No. 916.

U.S. Hydrographic Office, 1972: Sailing Directions (Enroute Japan). H.O. Pub. 156.

U.S. Naval Weather Service Environmental Detachment, Asheville, NC, 1973: Climatic Summaries for major Seventh Fleet ports and waters. NAVAIR 50-1C-62.

VII KOREA

1. GENERAL

Figure VII-1 shows the geographical location and topography of the Korean Peninsula in the western North Pacific Ocean. To the north, Korea is bounded by Manchuria, and to the extreme northeast by Soviet Siberia. Since almost one-third of the tropical cyclones affecting Inchon travel across the eastern coastal areas of China, and over 40% of the tropical cyclones affecting Pusan/Chinhae traverse southwestern Japan, the topography of the respective regions has also been included in Figure VII-1.

Since 1945 the Korean Peninsula has been divided into two states, the Republic of Korea (ROK) in the south and the Democratic People's Republic of Korea in the north. They are separated by a demilitarized zone along the armistice line of 1954.

Mountains ranging between 3000-6000 ft are found in the central and eastern portions of the Peninsula's tip. Along the eastern shore of the Korean Peninsula a 3000-6000 ft range extends north to the Manchurian border where two mountain ranges extend up to 9000 ft.

A detailed study of the coast and harbors of Korea is included in H. O. Pub. 157, Sailing Directions (Enroute) for the Coasts of Korea and China.

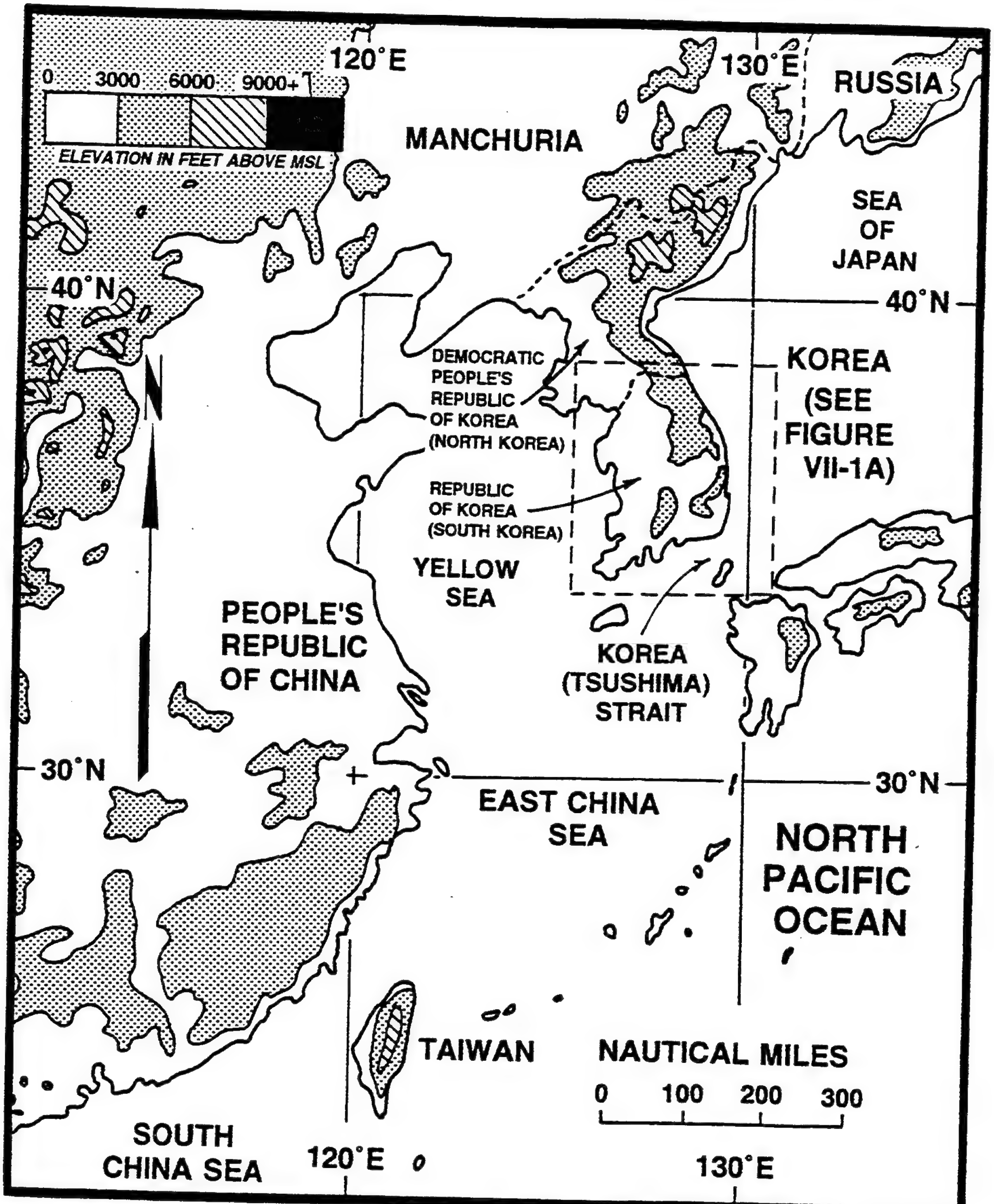

Figure VII-1. Locator map of the western North Pacific Ocean showing the positions and topographies of major land masses.

2. INCHON

SUMMARY

The conclusion reached in this study is that the port of Inchon is a typhoon haven only for ships berthed in the Non-Tidal Basin. A sortie is recommended for all ships not berthed in the Non-Tidal Basin. The reasons for a sortie include:

(1) Strong tidal currents in the Outer Harbor,

(2) The exposure of anchored vessels to wind,

(3) Varying holding qualities throughout the anchorage, and

(4) The potential for anchor dragging and resultant collisions in the anchorage.

Evasion to the Yellow Sea is the only practical sortie option available. Because tropical cyclones normally begin to weaken as they move over the relatively cooler waters of the Yellow Sea, the recommended evasion procedure is to sortie into the Yellow Sea and maneuver to place the ship in the navigable semicircle (the left semicircle with respect to the storm's direction of movement) of the storm's circulation and ride it out.

The only other sortie option available, transiting around the south coast of Korea and into the Sea of Japan, is not recommended because: (1) it would necessarily move the ship closer to the storm during the southward leg on the west side of Korea, and (2) it may place the ship in the stronger winds and higher seas in the dangerous semicircle (the right side of the storm with respect to the storm's direction of movement).

2.1 LOCATION

The port of Inchon, Republic of Korea (South Korea) is located at 37°28'N 126°36'E on the west coast of the Korean Peninsula (Figures VII-1, VII-1A and VII-2).

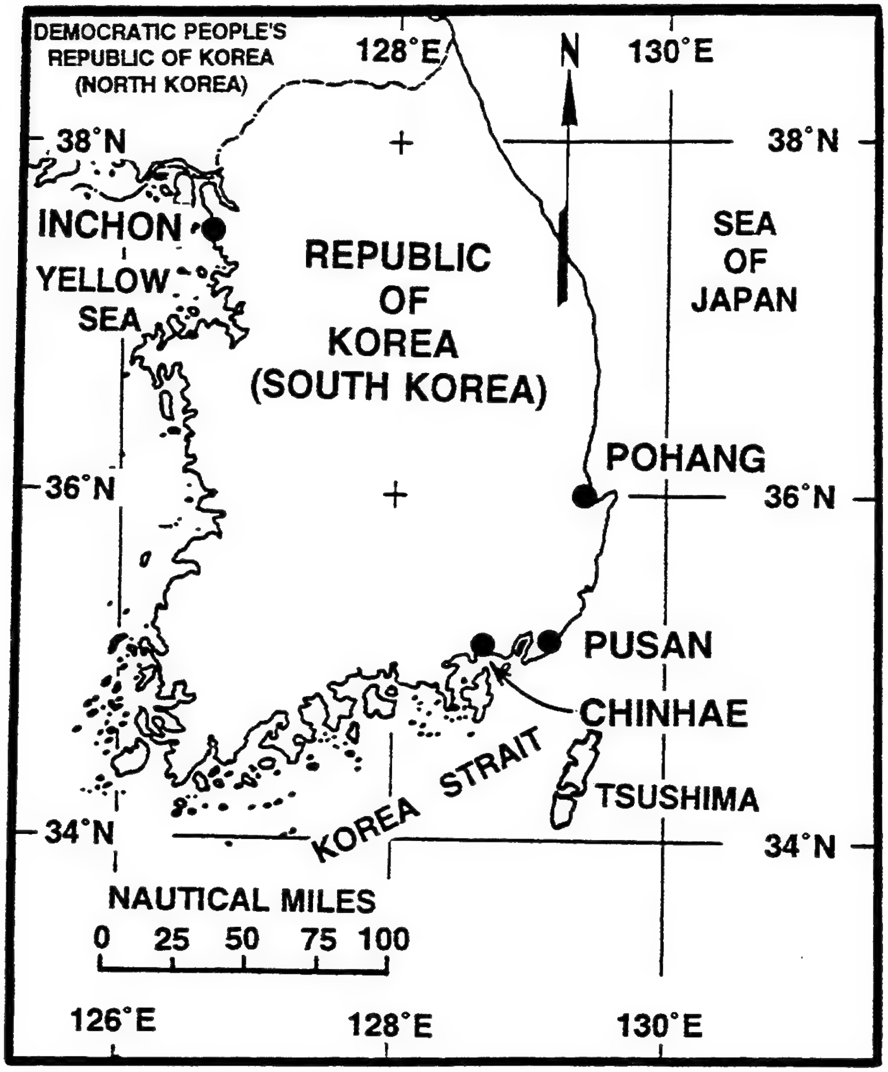

Figure VII-1A. Map of the Republic of Korea (South Korea) showing the locations of Inchon, Pusan, Chinhae, and Pohang.

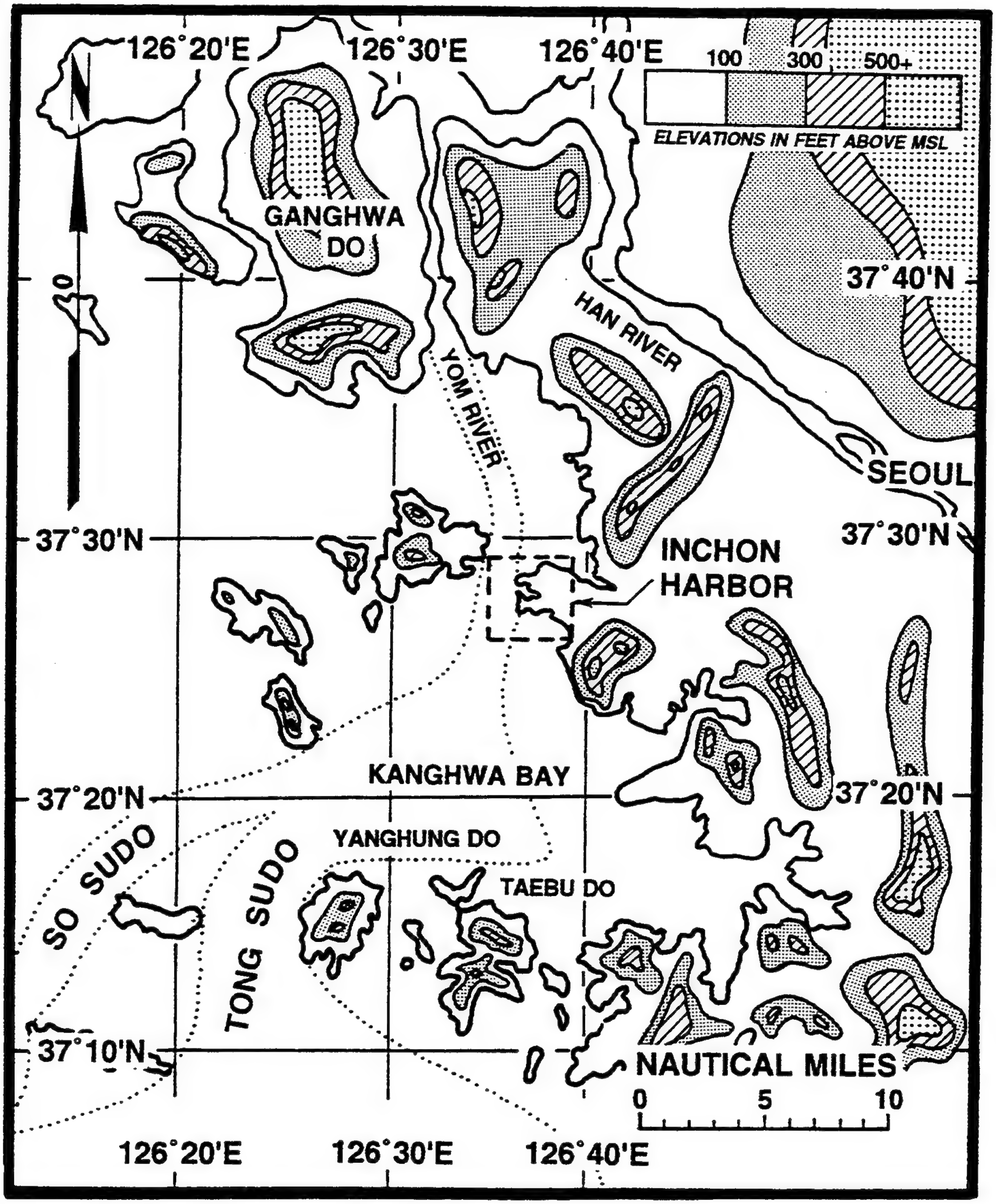

Figure VII-2. Approaches to the Port of Inchon and mesoscale topography around the port.

Seoul, the capital of South Korea, is located approximately 16 nmi east-northeast of the Port. Inchon is one of Korea's principal deep water ports, and serves as a commercial outlet and port of entry for Seoul.

The Port of Inchon is situated on the estuary of the Yom River, a secondary outlet of the 320 nmi long Han River, which flows through Seoul. As can be seen in Figure VII-2, the port is located at the north end of a long, split, 1,094 yd (1,000 m) wide channel. It narrows to a single, 295 yd (270 m) wide channel about 12 nmi southwest of the Port. Fleet Intelligence Center, Pacific (FICPAC) (1990) states that the southeasternmost branch of the split channel (Tong Sudo) is used for inbound traffic and the northwesternmost branch (So Sudo) is used for outbound traffic. The same document states that although the center fairway of the channel was clear during a visit by a U. S. Navy ship, the outer harbor fairway was encumbered by ships at anchor. See Section 2.2 below regarding the anchorage, channel enforcement, and ship movement.

2.2 INCHON HARBOR

Inchon Harbor is controlled and managed by the Inchon District Maritime and Port Authority and consists of an Outer Harbor, an Inner Harbor for coastal vessels, and a Non-Tidal Basin (also referred to in some documents as a Constant Tidal Basin) that can accommodate deep draft vessels up to 50,000 DWT (Figure VII-3).

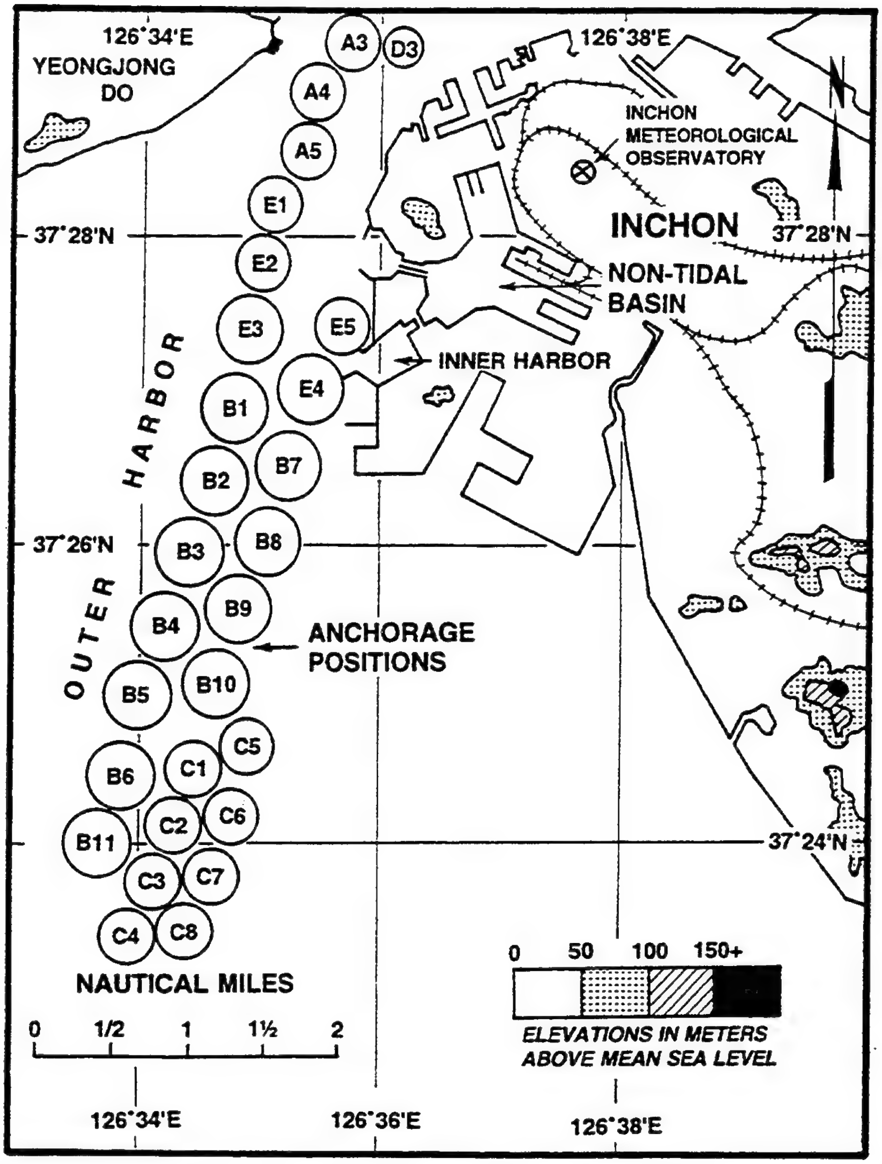

Figure VII-3. Inchon Harbor and local topography.

The Non-Tidal Basin is entered through either of two adjacent locks located between Wolmi Do and So Wolmi Do (Figure VII-4). The southern lock, with an overall length of 1,250 ft (381 m) and width of 118 ft (36 m), can accept vessels to 50,000 DWT. Length inside the gates is 890 ft (271 m). Maximum vessel dimensions at the lock are: length 570.8 ft (174 m), beam 101.7 ft (31 m), and draft 24.6 ft (7.5 m). The smaller,

northern lock, with an overall length of 945.7 ft (288.25 m) and width of 73.8 ft (22.5 m), can accommodate vessels to 10,000 DWT.

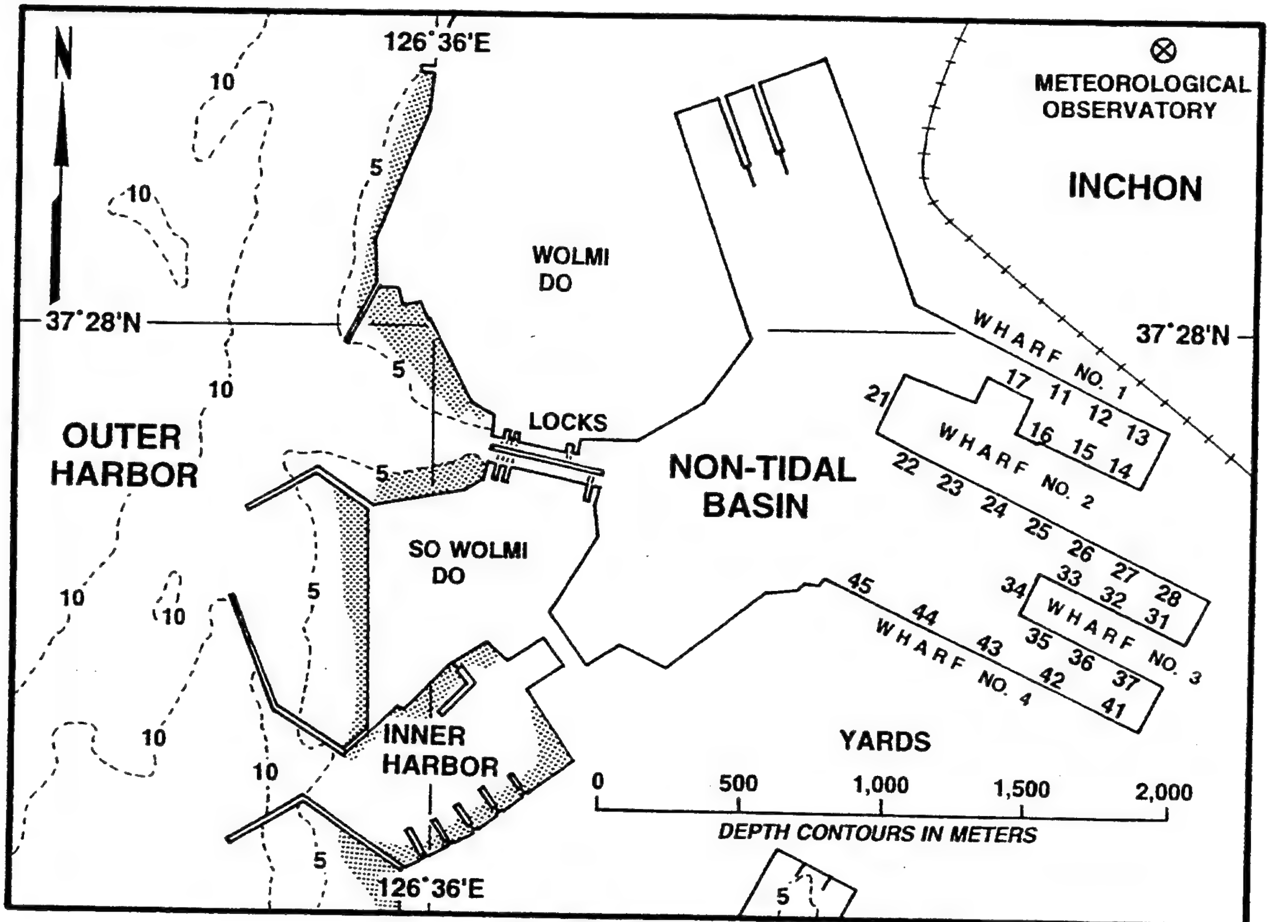

Figure VII-4. Port of Inchon.

Ships are admitted into the tidal basin only during slack tides because tidal currents just outside the lock gates set perpendicular to the lock entrances. Currents during ebb and flood tides commonly reach velocities of 3-4 kt. The locks are operated only during daylight hours because, according to local harbor personnel, "the workers go home at night." Port authorities state it takes approximately 1 to 1-1/2 hours to clear the locks.

The outer harbor consists of the Yom River Estuary area, which provides numerous anchorages for deep draft vessels. U. S. Navy ships are usually assigned to anchorages E-3 or E-4 (Figure VII-3). According to local port authorities, no aircraft carriers are allowed in the anchorage because of their size. Ships to 100,000 DWT have been accommodated on past occasions. Holding is rated good in E-3 and E-4 positions on a mud and sand bottom in an average of about 36 ft (11 m) depth (MLLW), with a minimum depth of 29.5 ft (9 m). Holding is best in the "B" designated anchorages while the "A" designated anchorages in the northern part of the harbor are said to offer poor holding on a rocky bottom.

FICPAC (1990) states that during a November 1989 visit by a U. S. Navy ship, there was little or no organization in the anchorage, and no clearly defined channel was enforced. Ships proceeded to the Non-Tidal Basin locks, or anchorages closer to the harbor, by steaming through other ships at anchor. The anchorage experiences strong tidal currents resulting from a normal tidal range of almost 30 ft (9 m).

The Inner Harbor (Figures VII-3 and VII-4) is used only by coastal vessels. It is located south of So Wolmi Do, with an entrance opening westward to the tidal estuary.

2.3 HARBOR FACILITIES

Facilities in the Non-Tidal Basin, the basin of primary interest to this study, are many and varied. Three general-use wharves, numbers 1, 2 and 3, have a total of 24 berths. According to a booklet published by the port, depths at the berths range from 24.6 to 39.4 ft (7.5 to 12 m) at wharf number 1: to 31 to 39 ft (9.5 to 12 m) at wharves 2 and 3. However, a Korean chart detailing the depths in the Non-Tidal Basin shows

depths along the three wharves range from 16.4 ft (5 m) to as low as 3.3 ft (1 m) when reduced to the approximate level of lowest low water. Since the water level in the Non-Tidal Basin is kept essentially constant by the lock system and a system of flood gates near the locks, and is not greatly affected by the rise and fall of astronomical tides (hence the reference as a Non-Tidal Basin), the booklet more accurately depicts depths at the piers. Berth 14 at wharf number 2 was used by a U. S. Navy vessel in 1989 (FICPAC, 1990). The berth was reported to have a length of 495 ft (151 m), an alongside depth of 26 ft (8 m), and neither steam nor electricity was available. All pier faces have built-in rubber fenders. According to local authorities, arrangements for CHT (sewage disposal), fresh water, and water taxis must be made through a shipping agent. The port can accommodate two CGN, CG, or AOR type ships at one time (FICPAC, 1990).

Other wharves and piers in the Non-Tidal Basin include a container terminal, a vehicle terminal for shipping automobiles, a grain import terminal, and scrap iron and other bulk commodity piers.

Mechanical handling facilities in the Non-Tidal Basin include mobile cranes from 10-ton to 40-ton capacities, and one 60-ton floating crane with a maximum lift above water of 84 ft (25.6 m) and overall maximum vertical lift of 140 ft (42.6 m).

There are no major repair facilities at the port. One small floating dry dock of 100-ton capacity is located in the Inner Harbor in an area of relatively shallow water.

A total of 22 tug boats of 3,000 hp are available at the port with advance notice advisable. Pilotage is not compulsory except when entering the locks and Non-Tidal Basin.

2.4 TOPOGRAPHY

South Korea has an abundance of mountain ranges running in all directions (Nestor, 1977). Approximately 70% of the total land surface is mountainous. Only about 15% of the land can be considered lowland, and this is mostly the product of erosion. Consequently, there are few areas devoid of hills that could be considered "plains" in the common usage of the word. Inchon is located on the Kimpo Plain in the Han River Lowlands.

The highest elevations of the rugged topography of South Korea are mostly aligned north-south along the eastern one-half of the country (Figure VII-1). Elevations in the hills and mountains east of Inchon generally range from 2,000 to 5,000 ft (610 to 1,524 m), with the highest peak on the peninsula, Chirisan, reaching 6,283 ft (1,915 m).

Inchon Harbor is afforded limited protection by hills generally exceeding 300-400 ft (91-122 m) within a few miles of the port in all directions except to the southwest. The 262+ ft (80+ m) height of Wolmi Do provides additional, limited protection from the northwest. See Figures VII-2, VII-3, and VII-4.

2.5 TROPICAL CYCLONES AFFECTING INCHON

2.5.1 Tropical Cyclone Climatology at Inchon

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Inchon is considered to represent a threat to the port. Table VII-1 contains a descriptive history of all 37 tropical storms and typhoons that passed within 180 nmi of Inchon during the 48-year period 1945-

1992. All of the tropical cyclone statistics used in this report are based on the data set used to compile Table VII-1.

Table VII-1. Descriptive history of the 37 tropical storms and typhoons passing within 180 nmi of Inchon during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	EVA	1945	AUG	4	9	40	19 (ENE)	360/31.4
2	URSULA	1945	SEP	13	17	44	82 (SSE)	054/23.8
3	LILLY	1946	AUG	20	8	33	20 (E)	013/13.1
4	PEARL	1948	JUL	7	6	50	20 (NW)	027/16.3
5	GRACE	1950	JUL	21	5	30	90 (SSE)	360/ 3.1
6	MARGE	1951	AUG	23	7	44	24 (E)	016/19.9
7	KAREN	1952	AUG	18	8	53	45 (ESE)	036/19.4
8	MARY	1952	SEP	3	10	45	28 (SE)	039/37.0
9	KIT	1953	JUL	6	5	45	55 (NNW)	053/24.0
10	AGNES	1957	AUG	21	7	45	81 (E)	006/25.3
11	BILLIE	1959	JUL	17	5	45	51 (WNW)	031/29.9
12	LOUISE	1959	SEP	7	11	37	56 (NNW)	074/19.9
13	SARAH	1959	SEP	17	14	96	167 (ESE)	039/23.9
14	CARMEN	1960	AUG	23	14	45	16 (SW)	023/37.4
15	BETTY	1961	MAY	28	6	36	165 (SSE)	061/32.8
16	HELEN	1961	AUG	3	12	27	33 (ESE)	014/10.7
17	JOAN	1962	JUL	10	5	40	38 (ESE)	035/26.1
18	NORA	1962	AUG	2	8	39	21 (W)	050/37.4
19	AMY	1962	SEP	7	17	34	9 (N)	058/36.0
20	SHIRLEY	1963	JUN	19	4	53	137 (SE)	044/29.2
21	FLOSSIE	1964	JUL	29	9	60*	114 (WNW)	024/25.2
22	HELEN	1964	AUG	2	11	62*	142 (SW)	321/15.4
23	BETTY	1966	AUG	30	16	30	109 (SSE)	053/ 8.1
24	BILLIE	1970	AUG	31	10	48*	71 (WNW)	019/12.7
25	RITA	1972	JUL	26	8	70	140 (SW)	324/29.8
26	IRIS	1973	AUG	17	10	34	17 (NW)	021/23.0
27	IRVING	1979	AUG	17	12	43	87 (SE)	052/23.1
28	CECIL	1982	AUG	14	12	30	98 (NNW)	067/11.2
29	JEFF	1985	AUG	2	7	45	177 (W)	021/16.9
30	KIT	1985	AUG	10	8	50*	100 (SE)	053/19.4
31	LEE	1985	AUG	14	9	50	88 (WNW)	013/30.9
32	VERA	1986	AUG	28	14	49	45 (SE)	034/20.2
33	THELMA	1987	JUL	15	5	55*	86 (ESE)	021/24.7
34	JUDY	1989	JUL	28	11	35	45 (ESE)	020/17.3
35	ABE	1990	SEP	2	15	32	26 (NW)	064/27.0
36	GLADYS	1991	AUG	23	14	31	159 (SSW)	289/ 9.5
37	TED	1992	SEP	24	20	40	108 (S)	075/27.2

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 37.5°N, 126.6°E.

Tropical cyclones which affect Korea generally have the same genesis area as those affecting Japan: 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the

seasonal changes of the synoptic environment. Most of the storms affecting Inchon move northwestward from the genesis area to the East China Sea before recurving northeastward across Korea or continuing northwestward across the Yellow Sea.

As can be seen in Table VII-2, the primary tropical cyclone season for Inchon is from July through September, although one storm of tropical storm intensity has occurred in each of the months of May and June. August is the month of greatest occurrence, with 51% (19 of 37) reaching their closest point of approach (CPA) during that month. Typhoon strength storms are rare when a storm is at CPA to Inchon. Only two occurrences are recorded, and those two were at a considerable distance from Inchon at CPA. One passed east of Inchon, and one passed west. The average movement for all storms at CPA is 029° at 23 kt. Thirty-two of the 37 storms were moving in a direction toward the northeast quadrant when at CPA, and three storms were moving toward the northwest quadrant. The remaining two were moving due north.

Table VII-2. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Inchon during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	1	1	9	19	7	0	0	0	37
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	1	0	1	0	0	0	2
Number of storms less than typhoon intensity at CPA	0	0	0	0	1	1	8	19	6	0	0	0	35
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	*	*	020	019	057	—	—	—	029
Average storm speed (knots) at CPA	—	—	—	—	*	*	23	20	28	—	—	—	23
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

* indicates insufficient storms for average direction and speed computations.

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During the 48-year period from 1945 through 1992 there were only 37 tropical storms and typhoons that met the 180 nmi threat criterion for Inchon, an average of only 0.77 per year. Figure VII-5 depicts the monthly distribution of the 37 storms by 7-day periods. As can be seen in the figure, the period of peak activity extends from early July through September.

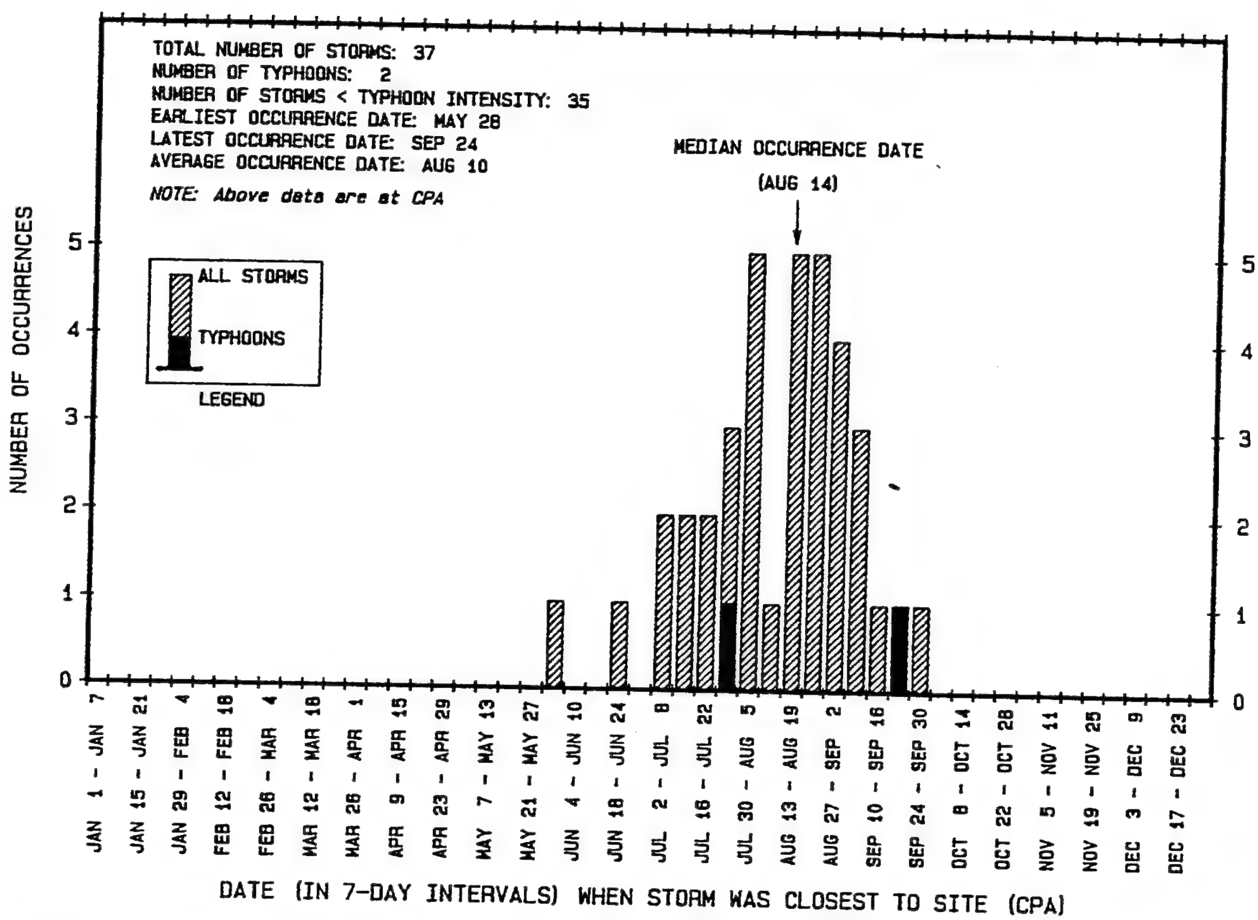

Figure VII-5. Monthly distribution of the 37 tropical storms or typhoons passing within 180 nmi of Inchon during the 48-year period 1945-1992.

Figure VII-6 depicts the annual distribution of tropical storms and typhoons passing within 180 nmi of Inchon

during the 48-year period 1945 through 1992. Most years have only a single occurrence, but seven of the years had more than one, with three of the seven years having three occurrences. The five-year period from 1974 through 1978 had no tropical storms or typhoons enter the 180 nmi threat radius around Inchon.

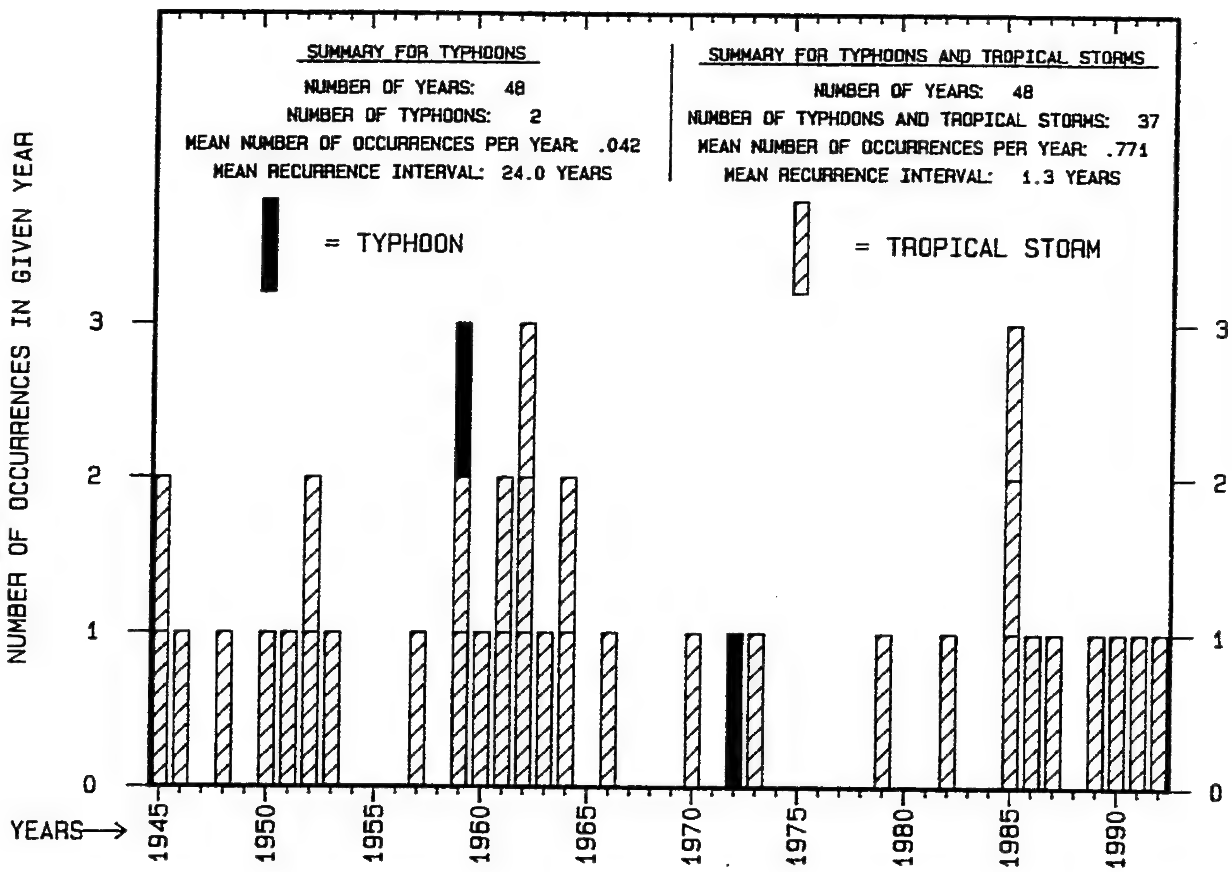

Figure VII-6. Chronology of the 37 tropical storms and typhoons passing within 180 nmi of Inchon during the 48-year period 1945-1992. The designation as tropical storm or typhoon is determined at time of closest point of approach (CPA) to Inchon.

Figure VII-7 depicts, on an 8-point compass, the octants from which the 37 tropical cyclones in the data set approached Inchon. Over 86% (32 of 37) of the storms approached Inchon from either the southwest (54%) or south (32%) octants.

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This was largely due to Korea's position relative to the primary tropical cyclone storm track discussed above, and Inchon's position on the west coast of Korea.

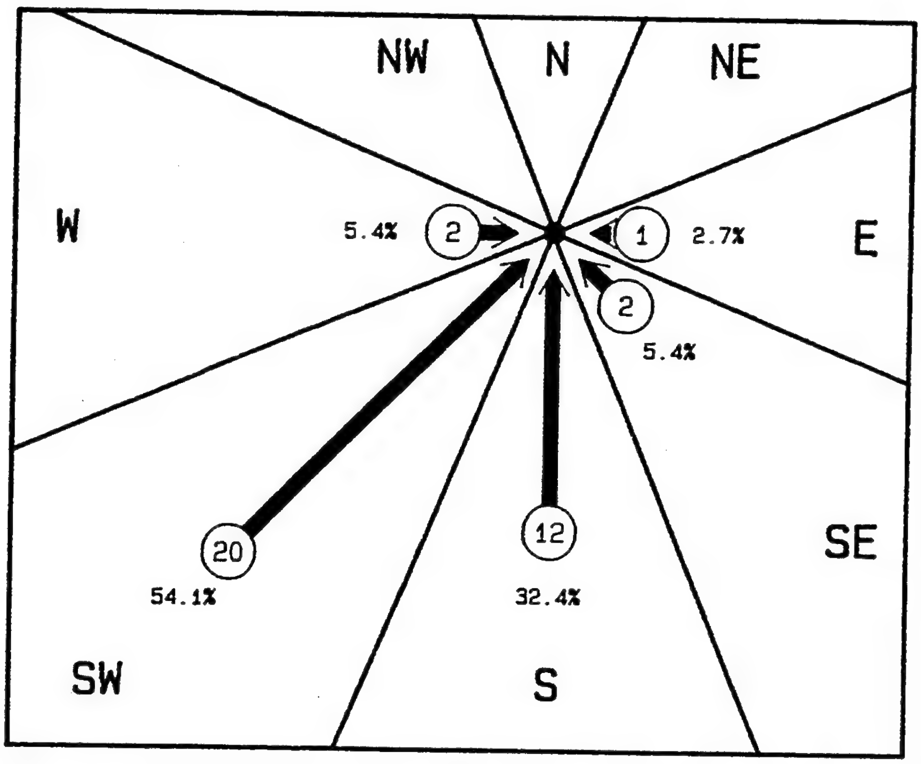

Figure VII-7. Directions of approach for the 37 tropical cyclones passing within 180 nmi of Inchon during the 48-year period of record. The length of the directional arrow is proportional to the number of storms given in the circles of each octant. Approach directions are determined at CPA.

Figures VII-8 and VII-9 provide information on the probability of remote tropical storms and/or typhoons passing within 180 nmi of Inchon and average time to CPA. The thinner lines represent a "percent threat" for any tropical cyclone location within the area depicted. The heavy, dashed lines represent the approximate time in days for a system to reach

Inchon. For example, in Figure VII-8, during the months of July and August a tropical cyclone located at 20°N 135°E has an approximate 18% probability of passing within 180 nmi of Inchon and will reach Inchon in about 4-1/2 to 6 days.

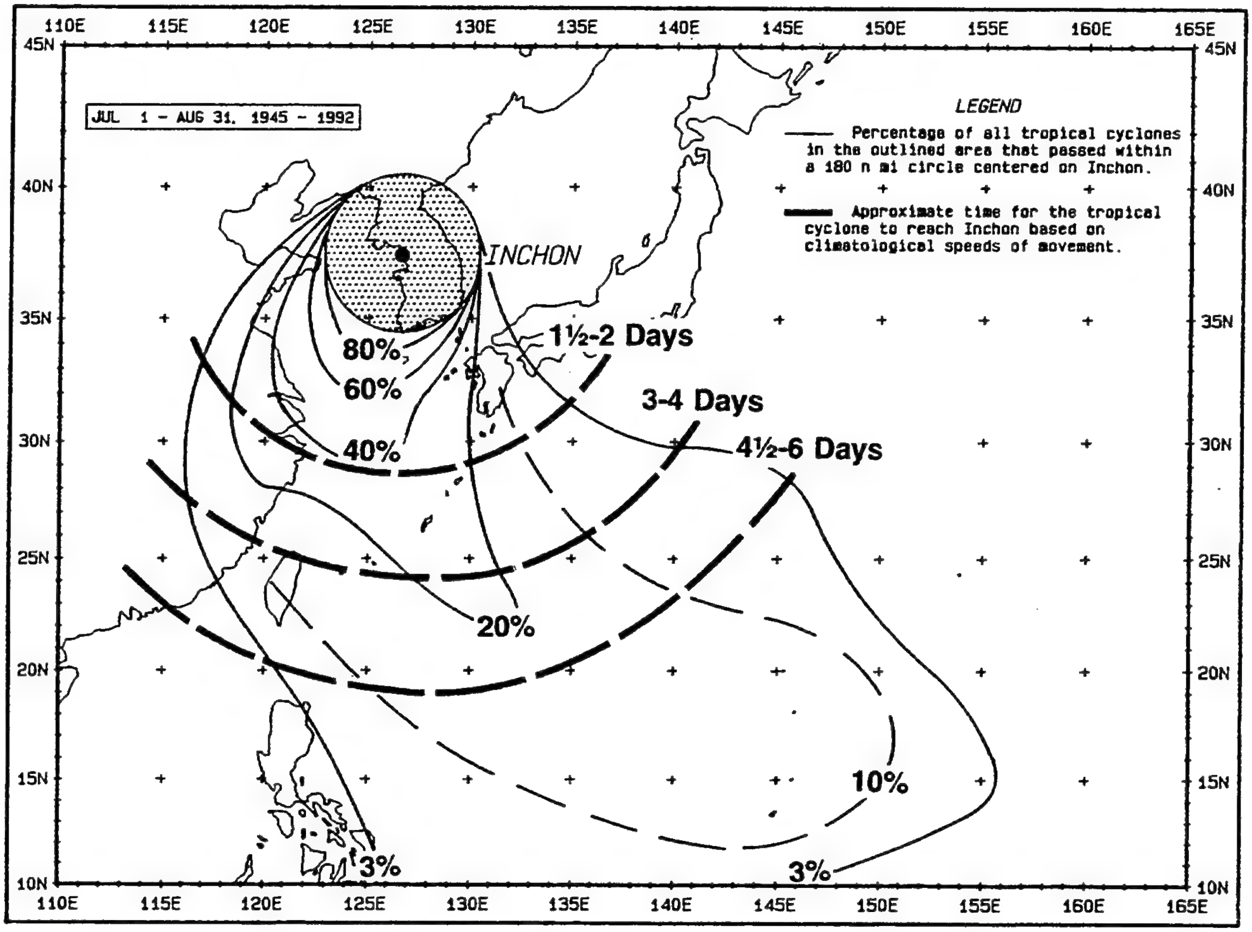

Figure VII-8. Probability that a tropical storm or typhoon will pass within 180 nmi of Inchon (circle), and approximate time to closest point of approach, during July and August.

A comparison of Figures VII-8 and VII-9 shows that there are distinct differences in threat axes according to time of year. The axis of the July and August storms (Figure VII-8) extends south from Inchon to approximately 28N before turning

southeastward to the more tropical latitudes. Figure VII-9, which presents the axis for the remaining ten months of the year, shows that those few storms affecting Inchon during those months have an axis that extends southwestward from Inchon across the East China Sea to the People's Republic of China before turning south along the Chinese coast and eventually southeastward across Taiwan to the Philippine Sea, east of the Philippine Islands.

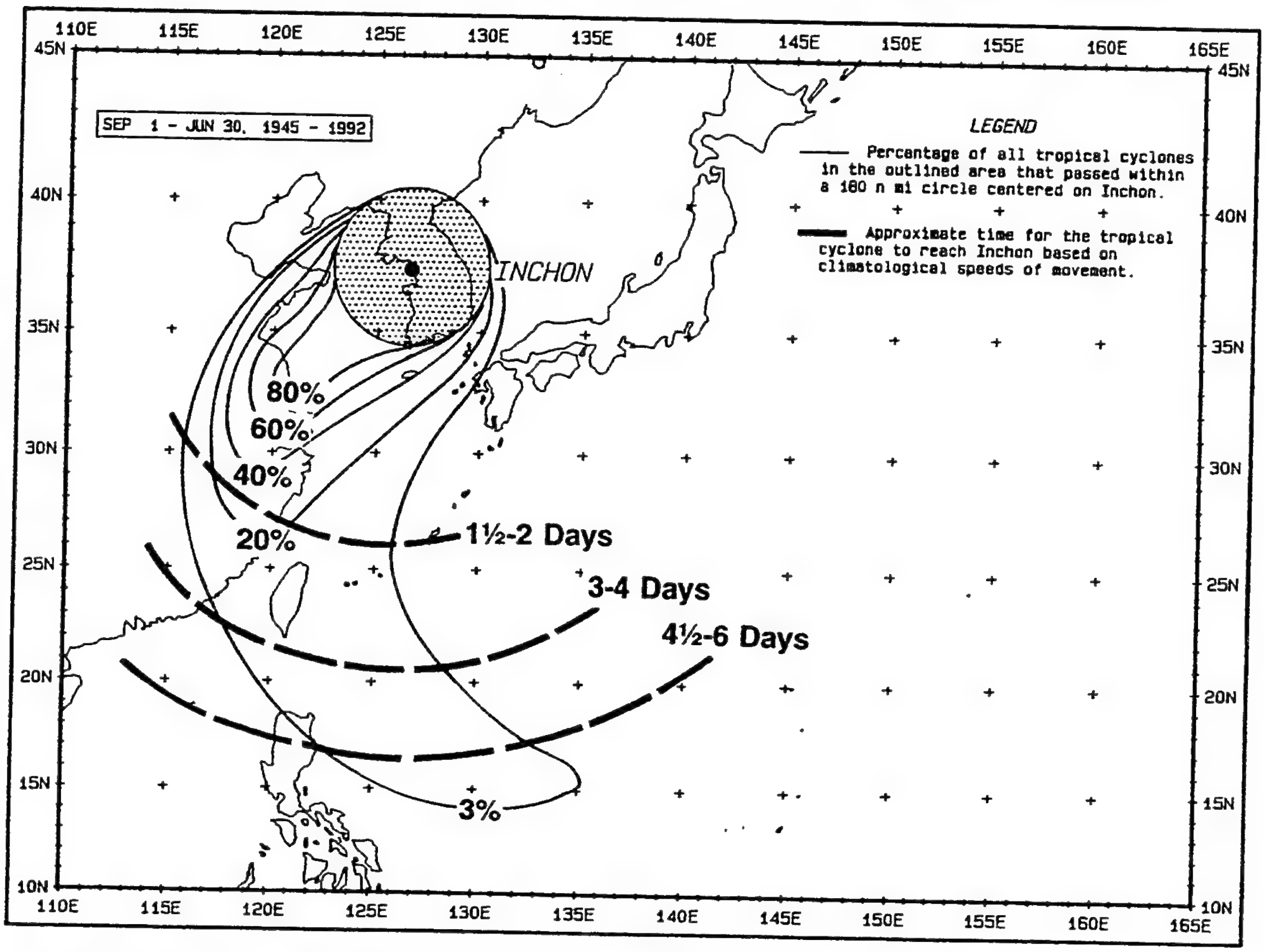

Figure VII-9. Probability that a tropical storm or typhoon will pass within 180 nmi of Inchon (circle), and approximate time to closest point of approach, during the period September through June.

2.5.2 Topographical Effects

The weather observation station for Inchon is located at 37°28'31"N 126°37'38"E atop a 267 ft (81 m) hill about 1/2 nmi northeast of the Non-Tidal Basin. The approximate location is indicated on Figure VII-3. Local authorities state that winds observed at the station closely approximate those at the port.

2.5.3 Local Weather Conditions

The data contained in Table VII-3 have been extracted from observations recorded at Kimpo Air Base (near Seoul at 37°33'N 126°48'E) during the period 1946-1959 and 1973-1992, and at Inchon for the period 1979-1992[1]. It should be noted that no record of observations is available for the period 1960-1972.

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[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

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Table VII-3. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Inchon. Observation sites and periods of coverage: Kimpo Air Base (near Seoul) 1946-1959 and 1973-1992, and Inchon 1979-1992. No data are available 1960-1972.

TROPICAL CYCLONE DATA				RELATED LOCAL WEATHER	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	WEATHER & OBSERVATION SITE
48/07/07 (PEARL)	027/16	324/20	50	SSE 35	RAIN KIMPO A/B
52/09/03 (MARY)	039/37	143/28	45	E 24G29	HEAVY RAIN KIMPO A/B
59/07/17 (BILLIE)	031/30	301/51	45	S 25G45	RAIN KIMPO A/B
82/08/14 (CECIL)	067/11	331/98	30	SSW 26G36	RAIN KIMPO A/B
85/08/02 (JEFF)	021/17	272/177	45	SSE 26G38	RAIN KIMPO A/B
85/08/13 (LEE)	013/31	289/88	50	S 36G56	RAIN KIMPO A/B
87/07/15 (THELMA)	021/25	118/86	55	WNW 25	RAIN KIMPO A/B
90/09/02 (ABE)	064/27	326/26	32	SSW 24	RAIN INCHON

A total of 37 tropical storms or typhoons passed within 180 nmi of Inchon during the period 1945 through 1992. Of these, 12 passed during the period 1960-1972, when observational data are not available. Nine of the remaining 25 storms caused winds ≥22 kt and two caused winds ≥34 kt at either Inchon or Kimpo Air Base (Table VII-3).

2.5.4 Wind

Whether or not a storm passes east or west of Inchon seems to make a significant difference as to the strength of observed winds. Of the nine storms causing winds of ≥22 kt, only two (Mary in 1952 and Thelma in 1987) passed east of Inchon. The remaining seven passed west of Inchon. The basic pattern of open sea to the west and terrain to the east, plus passage to the west placing Inchon in the "dangerous semi-circle" on the right side of the storm with respect to the direction of the storm's track, are probable causes of high winds with passage to the west. The two storms causing winds of ≥34 kt passed west of Inchon.

The beginning and end points of the arrows in Figure VII-10 give the positions of tropical cyclone centers when sustained winds ≥22 kt began and ended at Inchon or Kimpo Air Base for 9 of the 37 tropical cyclones that passed within 180 nmi during the periods 1946-1959 and 1973-1992. Similarly, Figure VII-11 shows the positions of the centers of the two tropical cyclones that brought sustained winds of ≥34 kt to Inchon or Kimpo Air Base for the same periods. Numbers adjacent to track arrowheads correspond to storm index numbers listed in Table VII-1.

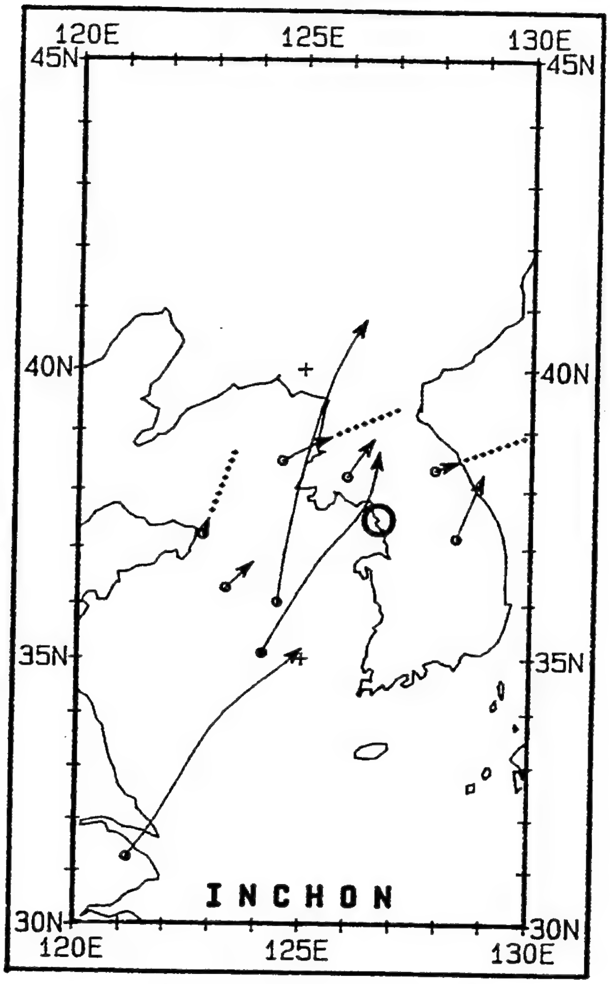

Figure VII-10.

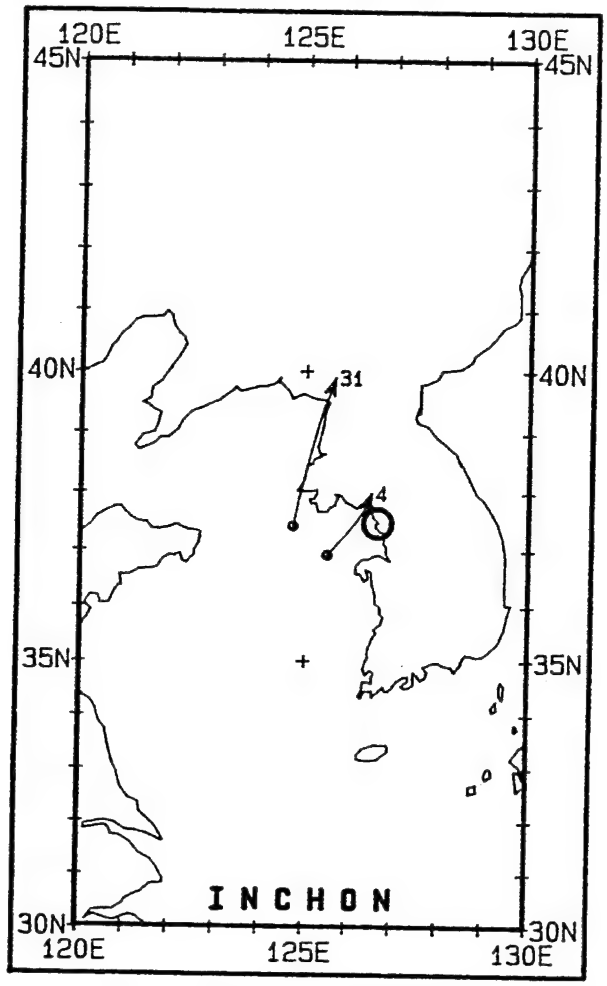

Figure VII-11.

Figures VII-10 and VII-11. Track segments of the tropical storms or typhoons causing sustained winds of ≥22 kt (Figure VII-10) and ≥34 kt (Figure VII-11) at Inchon or Kimpo Air Base (near Seoul) during the periods 1946-1959 and 1971-1992. Dots at the end of the tracks on Figure VII-10 indicate that the sustained winds continued beyond the time of the solid track segment shown. Numbers adjacent to track arrowheads in Figure VII correspond to storm index numbers listed in Table VII-1.

2.5.5 Wave Motion

Because it is a relatively small, enclosed basin, wave motion in the Non-Tidal Basin is limited to wind chop of about 4 ft (1.2 m) or less. Because of the limited wave motion, properly moored ships remaining in the basin during tropical cyclone passage should be able to remain at their berths with little difficulty.

Ships anchored in the outer harbor would be exposed to the full effects of wind and waves. The fetch north of the northernmost anchorage position (Figure VII-3) is approximately 8 to 10 nmi, and the waters are largely tidal flats with a narrow channel passing through the flats. Waves generated by northerly winds, therefore, would be fetch limited, and except for the narrow channel, would have to cross the tidal flats to reach the anchorage. Consequently, waves propagating from the north should not pose a significant hazard to ships in the anchorage.

The waters south and southwest of the port consist primarily of the channels bordered by scattered islands and tidal flats leading to the port. The possibility of waves high enough to hazard an anchored vessel would be dependent on the wind direction, the anchorage being used, and the level of the astronomical tide at the time of the strongest winds. The height of waves propagated from any direction other than 210°T to 240°T would be limited by an 8 to 10 nmi fetch and the tidal flats that border the ship channels.

Table VII-4, extracted from a prior evaluation of the Port of Inchon as a Typhoon Haven, presents the maximum wave heights to be expected at the locations specified.

Table VII-4. Maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in the outer harbor and the Non-Tidal Basin at Inchon.

LOCATION	OUTER HARBOR		NON-TIDAL BASIN
	NORTHERN PART	SOUTHERN PART	
Winds generally from the north (tropical cyclone passage east of Inchon)	5 ft	6 ft	4 ft
Winds generally from the south (tropical cyclone passage west of Inchon)	8 ft	7 ft	4 ft

The wave heights presented in Table VII-4 are intended as a guide only. Specific storms may generate waves that vary from those listed in the table.

Islands and tidal flats reduce the threat of waves from the west quadrant, and the Korean Peninsula eliminates any threat from the eastern semicircle.

2.5.6 Storm Surge and Tides

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

At Inchon, the potential for storm surge would be greatest if a strong tropical cyclone were approaching from the southwest or west and making landfall north of and within 30 nmi of the harbor. The normal 30 ft (9 m) tidal range of Inchon Harbor increases the potential for a significant storm surge. If the passage of the tropical cyclone were to coincide with a high astronomical tide, an extremely large rise in water level can be anticipated.

2.6 THE DECISION TO EVADE OR REMAIN IN PORT

2.6.1 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the NPMOCW/JTWC Guam Tropical Cyclone Warnings, and a basic understanding of weather will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures VII-8 and VII-9, discussed earlier, address the probability of existing tropical cyclones later affecting Inchon. As a further aid for the commander to evaluate a given situation, Figures VII-12 and VII-13 have been prepared. In contrast to Figures VII-8 and VII-9, Figures VII-12 and VII-13 consider only those storms which later passed within 180 nmi of Inchon. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and associated timing arcs

can be considered as an <u>average</u> approach scenario insofar as Inchon is concerned. It must be stressed that the other 50% of the storms which later affect Inchon will be <u>outside</u> of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures VII-12 and VII-13.

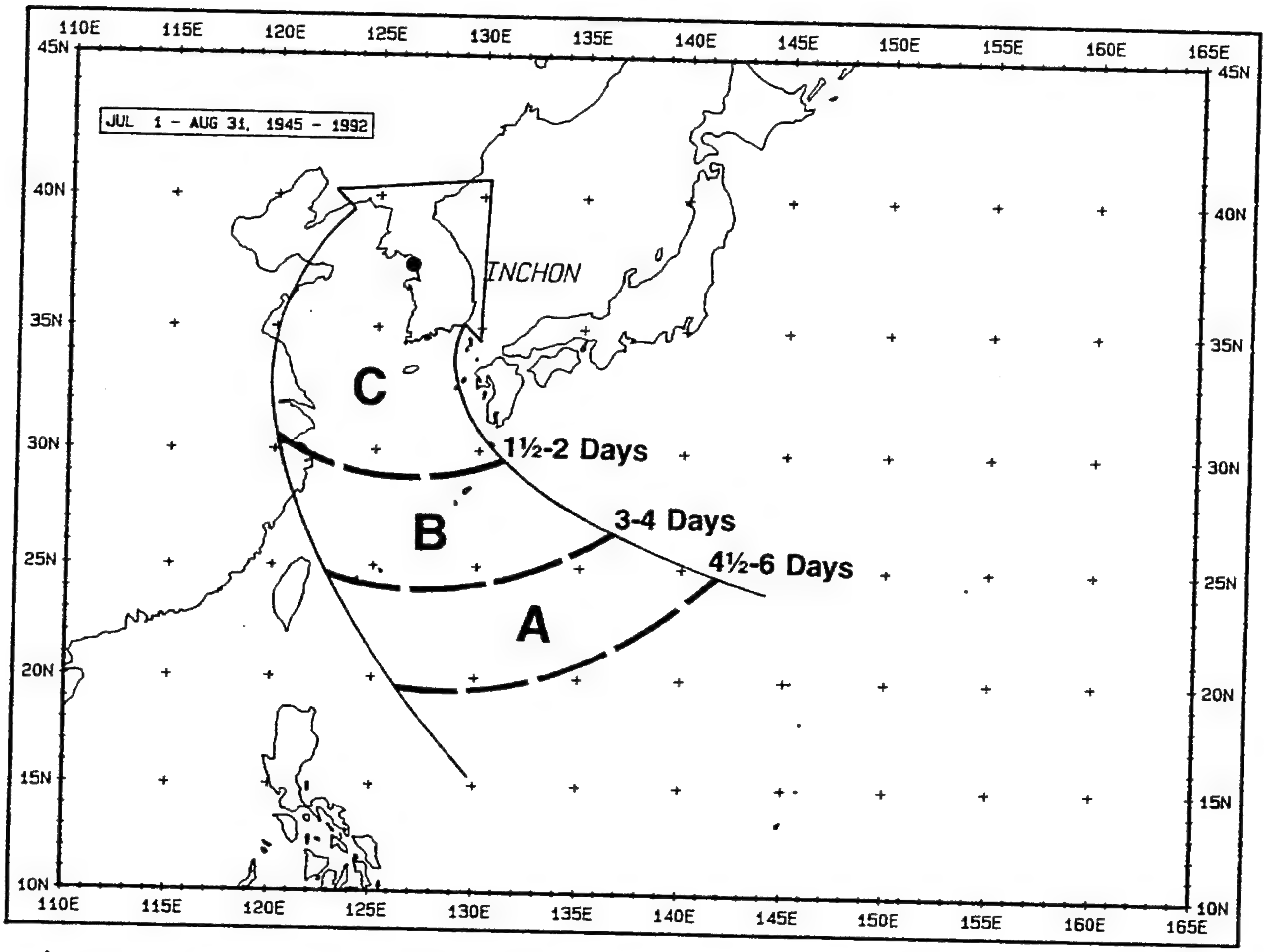

Figure VII-12. For the tropical cyclones passing within 180 nmi of Inchon during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Inchon. See Figure VII-8 for the areal pattern of actual probability of tropical cyclones passing within 180 mi of Inchon.

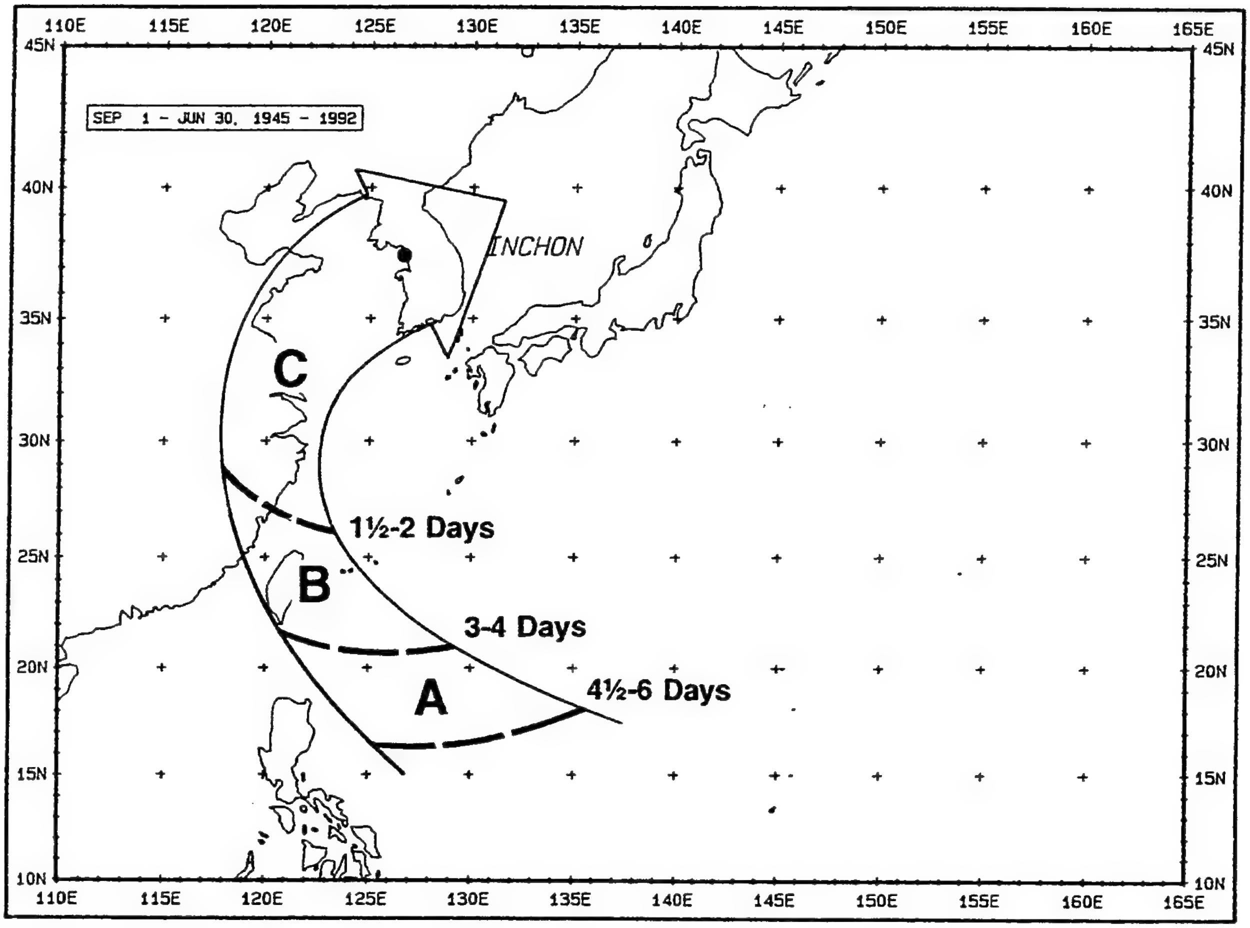

Figure VII-13. For the tropical cyclones passing within 180 nmi of Inchon during the period September through June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Inchon. See Figure VII-9 for the areal pattern of actual probability of tropical cyclones passing within 180 mi of Inchon.

INCHON

The following time/action sequence, to be used in conjunction with Figures VII-12 and VII-13 has been prepared to aid the commander in planning ship operations.

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

   a. Review material condition of ship. A sortie may be necessary in 48 hours.

   b. Reconsider any maintenance that would render the ship incapable of riding out a tropical storm or typhoon with the electrical load on ship's power (if remaining in Non-Tidal Basin), or would render the ship incapable of getting underway within 48 hours.

   c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters area B with forecast movement toward Inchon (recall that tropical cyclones tend to accelerate rapidly after they have recurved):

   a. Operational plans should be made in the event of a sortie.

   b. Reconsider any maintenance that would render the ship incapable of riding out a tropical storm or typhoon with the electrical load on ship's power (if remaining in Non-Tidal Basin), or would render the ship incapable of getting underway within 24 hours.

   c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone enters area C moving toward Inchon:

   a. Execute plans made in previous steps.

   b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

2.6.2 Remaining in Port

For ships moored in the Non-Tidal Basin, remaining in port is the recommended course of action when a tropical cyclone threatens Inchon. Berths and bollards are in good repair, all berths have built-in rubber fenders, and wave height in the basin should be limited to no more than about 4 ft.

The following actions should be considered when a tropical cyclone is threatening Inchon:

(1) All items capable of becoming flying projectiles in a strong wind should be removed or otherwise secured.

(2) Extra attention should be given to the mooring lines and to the brow during the passage of the storm. Crews should have extra line and wire available and be ready to tend lines during the storm's passage.

Ships at the port that are not moored in the Non-Tidal Basin will be utilizing the anchorage and, as discussed in Section 2.6.3 below, should be prepared to get underway and sortie from the port.

2.6.3 Evasion

Evasion from Inchon Harbor is the recommended course of action for all U. S. Navy ships not moored in the Non-Tidal Basin. Remaining at anchor in the outer harbor is not recommended because of:

(1) The strong tidal currents,

(2) The exposure of the vessels to wind,

(3) Varying holding qualities throughout the anchorage,

(4) The potential for anchor dragging and resultant collisions in the anchorage.

As listed in Table VII-3 above, the maximum wind recorded at Inchon or Kimpo Air Base near Seoul during the periods 1946-1959 and 1973-1992, was south at 36 kt with gusts to 56 kt during the passage of Tropical Storm Lee in August 1985. The relatively low maximum velocity is at least partly due to the fact that most of the tropical cyclones affecting Inchon are of less than typhoon strength as they approach Inchon. The storms begin to lose intensity as they move over the relatively cooler waters of the Yellow Sea and begin interaction with extratropical air masses as they move northward. Therefore, it is felt that the best evasion procedure is to move into the Yellow Sea and maneuver to place the ship in the navigable semicircle (the left semicircle with respect to the storm's direction of movement) of the storm's circulation. In all cases, Optimum Track Ship Routing (OTSR) should be consulted as to the best evasion option.

Since the waters near Inchon Harbor are restricted and the currents in the approach channels may be quite strong (reported to be as fast as 8 kt in So Sudo Channel (Figure VII-2)), evasion must begin early in the decision process. Given a strong north-setting current, a ship steaming at 10 kt may require 6 hours to clear the outer harbor and reach the open waters of the Yellow Sea. Another factor to be considered when planning a sortie is the potential congestion near the anchorage and in the ship channels as fishing vessels and other smaller craft seek shelter from the storm.

An evasion procedure used by large vessels of the ROK Navy is to anchor just north of Taebu Do or Yanghung Do, islands approximately 10 nmi south of Inchon (Figure VII-2). Since there are rocks and shallow areas in the waters around the islands,

commanders who are unfamiliar with the area may find this option attractive only in emergency situations.

Whichever option is chosen, ship captains should remember that tropical cyclones are historically unpredictable, especially in the recurvature phase. The 48-hour forecast position error may exceed 200 nmi. Consequently, the storm may be closer to or farther from Inchon than the forecast indicates, or be right or left of its forecast track.

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with LT G. W. Fournier, USN and QM1 S. H. Thayer, USN of Commander Naval Forces, Korea; Mr. Jun Kue Han, Director, Port Operation Division, Inchon District Maritime and Port Authority; Mr. In Soo Lee, Assistant Director, Port Operation Division, Inchon District Maritime & Port Authority; and LCDR Youn, Republic of Korea Navy, to obtain much of the information contained in this port evaluation.

REFERENCES

FICPAC, 1990: Port Directory for Inchon South Korea, Change 11. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Nestor, W. J. R., 1977: The Environment of South Korea and Adjacent Sea Areas. NAVENVPREDRSCHFAC Technical Report No. 77-03. Published by Naval Research Laboratory (formerly Naval Environmental Prediction Research Facility), Monterey, CA 93943.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

3. PUSAN

SUMMARY

The conclusion reached in this study is that the port of Pusan is not a typhoon haven. All U. S. Navy ships should sortie when the harbor is threatened by a tropical cyclone. The reasons for a sortie include:

(1) The lack of protection from wind in the harbor,

(2) The vulnerability of Pusan harbor to storm surge, and

(3) The close proximity of Chinhae Bay, a highly regarded typhoon haven.

Evasion to the Yellow Sea or the Sea of Japan are the open ocean sortie options available. The choice will depend on the strength and forecast track of the approaching storm and how early in the planning process the sortie decision is made.

If remaining in Korean waters is preferred to evading at sea, anchoring in nearby Chinhae Bay is an option that should be considered. Chinhae Bay is highly regarded as a good haven in all but the strongest tropical cyclone situations.

3.1 LOCATION

The Port of Pusan is located on the southeast coast of the Republic of Korea at 35°05'N 129°06'E (Figures VII-1A and VII-14).

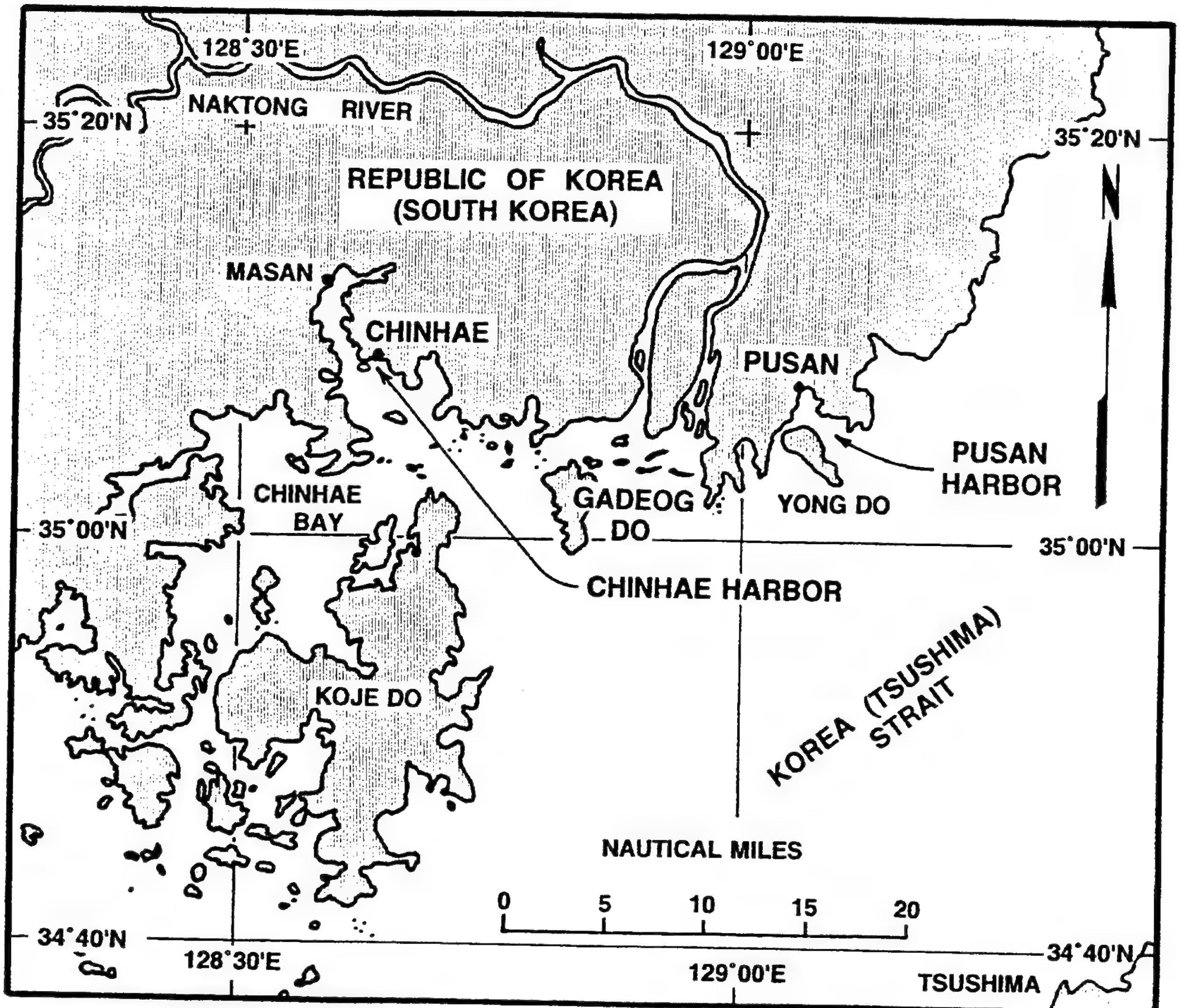

Figure VII-14. Location of Pusan on the southeastern coast of the Korean Peninsula.

3.2 PUSAN HARBOR

Pusan Harbor, the Republic of Korea's principal deep water port, is divided by Yong Do (island) into northern and southern harbors (Figure VII-15.) Each of the harbors is further divided into inner and outer harbors. North Harbor accommodates deep-draft ocean-going vessels, while South Harbor is used primarily by coastal vessels. Unless otherwise stated, references to the

Port of Pusan in this study will specifically apply to the North Harbor.

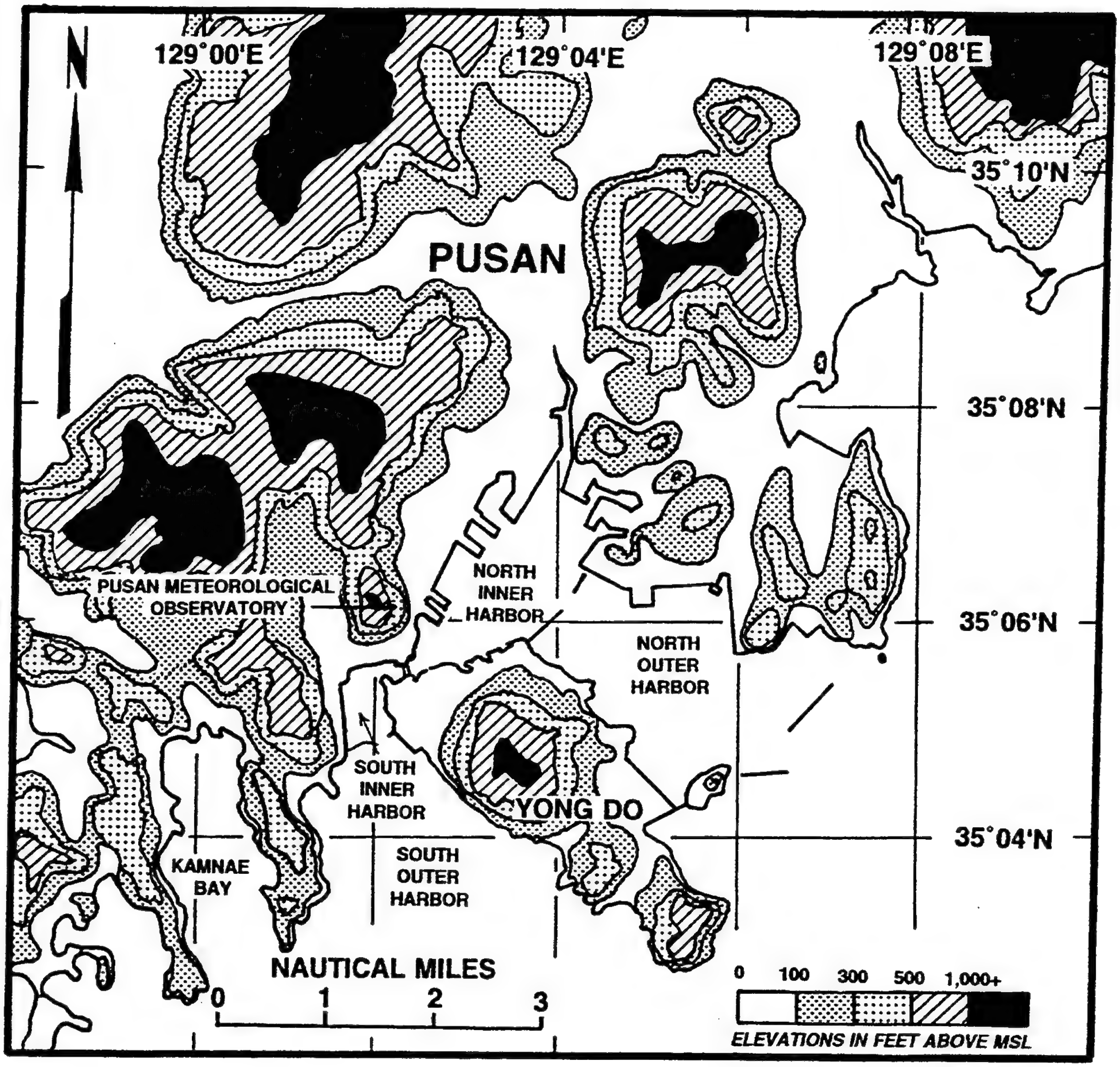

Figure VII-15. Pusan Harbor and surrounding topography.

As of September 1993, an extensive construction project was underway to fill a portion of the outer harbor in order to build a container pier, and fill a relatively shallow portion of the

inner harbor to accommodate the development of additional, unspecified port facilities. The new construction areas are indicated on Figure VII-16. In addition, plans call for the future development of new port facilities in several sections of the inner harbor, and the eastward extension of the easternmost outer breakwater to the coastline. Local harbor personnel state that such construction would not likely occur until after the year 2000, however.

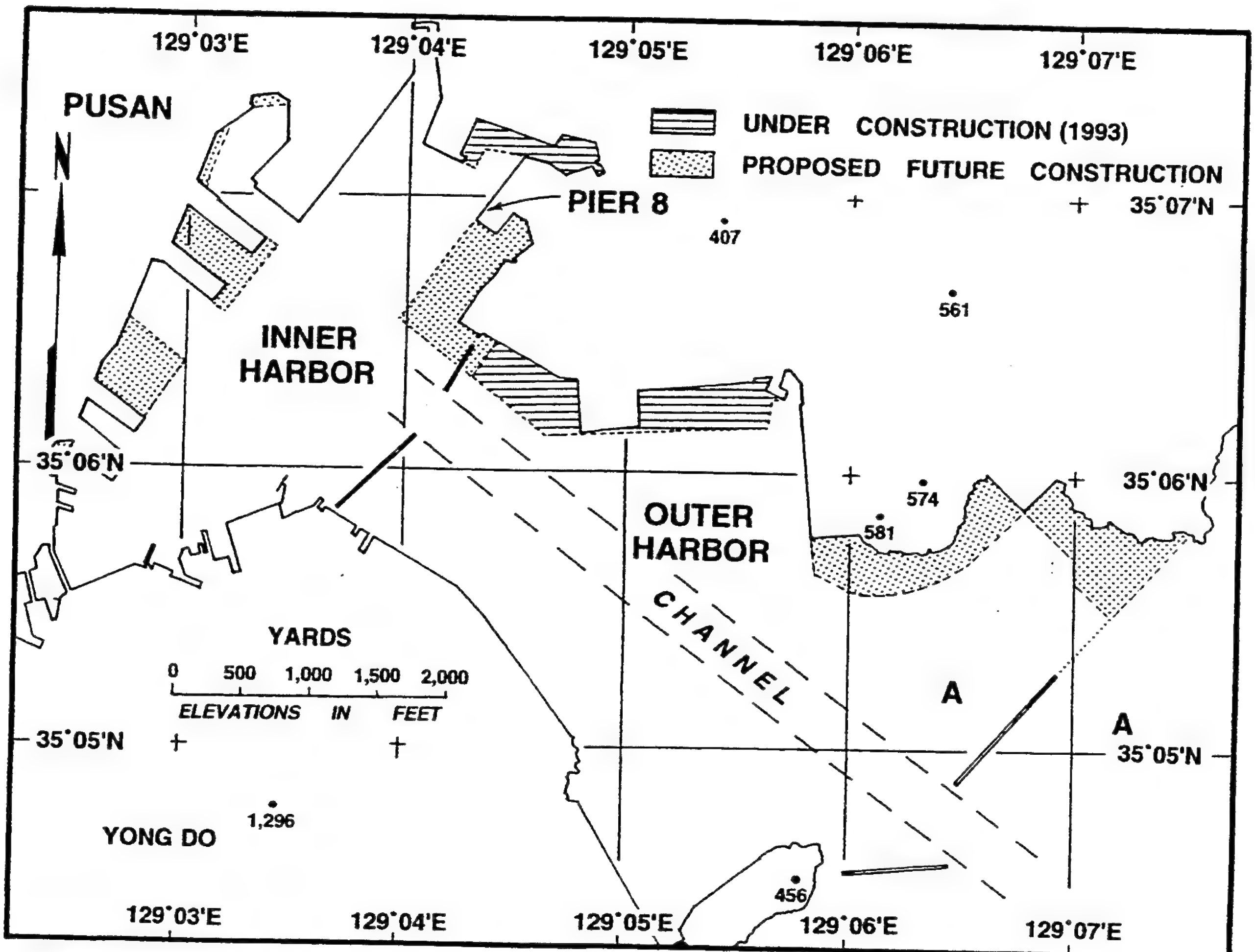

Figure VII-16. Pusan's North Inner and Outer Harbors.

Pusan has designated anchorages inside and outside the outer breakwater, as indicated by the letters "A" on Figure VII-16, as

well as in the inner harbor. U. S. Navy ships use the anchorages on either side of the outer breakwater while the inner harbor anchorages are used exclusively by commercial vessels. The designated nuclear power anchorage was moved from inside to outside the outer breakwater in 1993. The outer anchorage does not offer any protection from southerly winds or seas. As a result, liberty boat and ferry runs to/from vessels anchored in the outer anchorage are often cancelled whenever wind speeds approach 30 kt. Each of the anchorages used by U. S. Navy ships offers good holding on a mud bottom.

The astronomical tide range in Pusan Harbor is relatively small, ranging from a spring rise of 4 ft (1.2 m) and neap rise of 3 ft (0.9 m). Currents are correspondingly weak, about 0.6 kt. However, higher velocities are observed during maximum ebb and flood flow at two locations: (1) at the drawbridge in the narrows between Yong Do and the mainland between the North and South Inner Harbors, and (2) in the channel between the breakwaters separating the North Inner and Outer Harbors.

3.3 HARBOR FACILITIES

The North Inner Harbor is composed of several piers, quays, and deep-draft anchorages. Most of the facilities are privately owned and not available for use by U. S. Navy ships. Pier 8, indicated on Figure VII-16, is controlled by the U. S. Military Sealift Command, however, and is frequently used by U. S. Navy vessels. Pier 8 is large enough to handle very large ships, with Forrestal class aircraft carriers being accommodated in the past. The pier has 29.5 to 32.8 ft (9 to 10 m) depths alongside,but if greater depths are needed, ships are breasted out as necessary to deeper water.

Pilotage is compulsory at Pusan. Harbor tugs are available, with 1 to 2 days notice of tug requirements advisable. Other facilities at the port include heavy lift cranes, dry docks, and other equipment normally associated with a busy, deep-water port.

3.4 TOPOGRAPHY

South Korea has an abundance of mountain ranges extending in all directions (Nestor, 1977). Approximately 70% of the total land surface is mountainous. Only about 15% of the land can be considered lowland, and this is mostly the product of erosion.

The highest elevations of the rugged topography of South Korea are mostly oriented north-south along the eastern one-half of the country. The highest elevations within 60 nmi north and west of Pusan are in the 500 to 3,000 ft range.

As can be seen in Figure VII-15, Pusan is afforded limited protection by elevations exceeding 1,000 ft north, west and south of the harbor, but is open and exposed to east-northeasterly, southeasterly and southwesterly winds.

3.5 TROPICAL CYCLONES AFFECTING PUSAN

3.5.1 Tropical Cyclone Climatology at Pusan

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Pusan is considered to represent a threat to the port. Table VII-5 contains a descriptive history of all 77 tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992. All of the tropical cyclone statistics used in this report are based on the data set used to compile Table VII-5.

Table VII-5. Descriptive history of all tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	EVA	1945	AUG	4	9	40	101 (W)	360/26.0
2	URSULA	1945	SEP	13	17	43	102 (NW)	058/23.5
3	LILLY	1946	AUG	20	8	44*	50 (W)	336/ 8.5
4	DELLA	1949	JUN	21	2	50	101 (E)	001/11.5
5	FAYE	1949	JUL	18	4	43*	71 (E)	011/ 8.2
6	JUDITH	1949	AUG	17	8	27	44 (SE)	051/ 3.2
7	ELSIE	1950	JUN	24	3	55	52 (SSE)	035/38.2
8	GRACE	1950	JUL	21	5	34	101 (W)	360/12.2
9	KEZIA	1950	SEP	13	9	51	101 (ESE)	007/26.1
10	MARGE	1951	AUG	23	7	48	133 (WNW)	021/21.3
11	KAREN	1952	AUG	18	8	56	133 (WNW)	033/23.3
12	MARY	1952	SEP	3	10	45	155 (NW)	038/37.3
13	GRACE	1954	AUG	18	4	64	163 (SE)	043/ 9.2
14	KATHY	1954	SEP	7	9	50*	131 (ESE)	014/21.4
15	JUNE	1954	SEP	13	10	63*	129 (E)	012/27.6
16	LOUISE	1955	SEP	30	15	82	116 (E)	012/26.4
17	MARGE	1955	OCT	3	16	53	162 (ESE)	022/21.0
18	BABS	1956	AUG	16	9	80	87 (SE)	051/20.4
19	EMMA	1956	SEP	9	12	103	29 (ESE)	030/28.6
20	VIRGINIA	1957	JUN	27	5	50	97 (S)	074/34.0
21	AGNES	1957	AUG	21	7	45	50 (W)	005/25.1
22	SARAH	1959	SEP	17	14	98	12 (NW)	034/24.5
23	CARMEN	1960	AUG	22	14	46	170 (WNW)	022/25.9
24	BETTY	1961	MAY	28	6	35	18 (N)	061/32.7
25	HELEN	1961	AUG	2	12	40	60 (W)	346/10.3
26	JOAN	1962	JUL	10	5	40	139 (NW)	031/26.6
27	SARAH	1962	AUG	21	13	32	170 (SE)	038/13.1
28	SHIRLEY	1963	JUN	19	4	53*	48 (NW)	044/29.2
29	BESS	1963	AUG	10	9	38*	72 (E)	360/ 8.3
30	HELEN	1964	AUG	2	11	75	152 (WSW)	328/12.1
31	KATHY	1964	AUG	24	15	60*	155 (SE)	034/11.7
32	DINAH	1965	JUN	20	10	35	151 (ESE)	026/24.4
33	JEAN	1965	AUG	6	16	79	122 (ESE)	030/23.7
34	BETTY	1966	AUG	30	16	30	87 (WNW)	053/ 8.1
35	POLLY	1968	AUG	16	7	40	26 (ESE)	045/28.1
36	DELLA	1968	SEP	25	15	35	140 (SE)	024/12.9
37	WILDA	1970	AUG	14	8	70	114 (SE)	036/21.7
38	ANITA	1970	AUG	21	9	78	162 (E)	358/18.6
39	BILLIE	1970	AUG	30	10	71	172 (WSW)	340/10.5
40	OLIVE	1971	AUG	5	19	58*	67 (ESE)	017/17.5
41	TESS	1972	JUL	23	10	44	85 (E)	002/20.1
42	IRIS	1973	AUG	17	10	42	173 (WNW)	018/21.0
43	GILDA	1974	JUL	6	9	48*	11 (SE)	031/18.8
44	POLLY	1974	SEP	1	18	52	172 (ENE)	348/20.6
45	PHYLLIS	1975	AUG	17	7	42	69 (ENE)	345/ 8.1
46	THERESE	1976	JUL	19	9	47*	141 (SSE)	077/ 6.2
47	FRAN	1976	SEP	12	17	48	99 (ESE)	027/20.2
48	POLLY	1978	JUN	20	3	32	121 (SSE)	064/18.1
49	WENDY	1978	AUG	2	8	40	120 (SE)	024/16.9
50	CARMEN	1978	AUG	20	11	30	112 (W)	013/19.7
51	IRMA	1978	SEP	15	18	43	100 (SSE)	064/17.7
52	IRVING	1979	AUG	17	12	43*	97 (NW)	052/23.1
53	ORCHID	1980	SEP	11	17	53	133 (E)	012/30.7
54	OGDEN	1981	JUL	31	10	40	126 (SSW)	284/14.0
55	ELLIS	1982	AUG	27	14	48	146 (E)	358/21.0
56	KEN	1982	SEP	25	20	45	171 (E)	357/22.0
57	FORREST	1983	SEP	28	11	63*	139 (SSE)	076/30.2
58	HOLLY	1984	AUG	21	11	58*	33 (SSE)	045/17.3
59	KIT	1985	AUG	10	8	47*	84 (NNW)	052/19.4
60	ODESSA	1985	AUG	31	12	44	74 (ESE)	038/18.3

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.1°N, 129.1°E.

Table VII-5 (continued). Descriptive history of all tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
61	PAT	1985	AUG	31	13	78	73 (ESE)	018/23.9
62	BRENDA	1985	OCT	5	20	65	94 (SW)	042/25.9
63	NANCY	1986	JUN	25	5	45	45 (SE)	044/29.7
64	VERA	1986	AUG	28	14	53	131 (WNW)	029/17.0
65	THELMA	1987	JUL	15	5	63*	74 (WNW)	018/25.4
66	DINAH	1987	AUG	30	11	72	21 (ESE)	033/33.3
67	ELLIS	1989	JUN	24	6	35	113 (ESE)	021/23.2
68	JUDY	1989	JUL	28	11	50*	77 (WSW)	336/15.3
69	ZOLA	1990	AUG	22	14	86	173 (E)	009/21.2
70	CAITLIN	1991	JUL	29	9	72	31 (SE)	037/18.9
71	GLADYS	1991	AUG	23	14	40	75 (SW)	313/ 9.2
72	KINNA	1991	SEP	13	19	77	120 (SE)	039/27.6
73	MIREILLE	1991	SEP	27	21	90	108 (SE)	042/38.9
74	IRVING	1992	AUG	5	10	25	19 (SSW)	025/ 7.7
75	JANIS	1992	AUG	8	11	75	138 (SE)	042/17.7
76	KENT	1992	AUG	19	12	30	91 (E)	003/11.2
77	TED	1992	SEP	24	20	38	61 (NNW)	074/29.4

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.1°N, 129.1°E.

Tropical cyclones which affect Korea generally have the same genesis area as those affecting Japan: 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment. Most of the storms affecting Pusan move northwestward from the genesis area to the East China Sea or western Philippine Sea south of the island of Kyushu, Japan before recurving on a north or northeastward track and passing within 180 nmi of Pusan.

A review of Table VII-6 shows that the primary tropical cyclone season for Pusan is from June through September, with 96% of the storms (74 of 77) occurring during that period. August is the month of greatest threat, with 49% (38 of 77) reaching their closest point of approach (CPA) during the month. One storm of less than typhoon intensity at CPA occurred in May, and two

storms, one of typhoon strength and one of less than typhoon strength at CPA, have occurred in October.

Table VII-6. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	1	8	10	38	18	2	0	0	77
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	1	11	5	1	0	0	18
Number of storms less than typhoon intensity at CPA	0	0	0	0	1	8	9	27	13	1	0	0	59
Average heading (degs) towards which storms were moving at CPA	---	---	---	---	*	038	013	017	030	*	---	---	023
Average storm speed (knots) at CPA	---	---	---	---	*	26	17	17	26	*	---	---	20
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

The average movement for all storms at CPA is 023° at 20 kt. Sixty-two of the 77 storms (81%) were moving northeast when at CPA, three were moving due north, and 12 were moving northwest.

During the 48-year period from 1945 through 1992 there were 77 tropical storms and typhoons that met the 180 nmi threat criterion for Pusan, an average of 1.6 per year. Figure VII-17 depicts the monthly distribution of the 77 storms by 7-day periods. As can be seen in the figure, the period of peak activity extends from late July through September. The threat period at Pusan is essentially limited to the period of June through September. Storms have occurred outside those months, but the one storm recorded in May occurred late in the month, on the 28th, while the two October storms occurred by the 5th of the month.

PUSAN

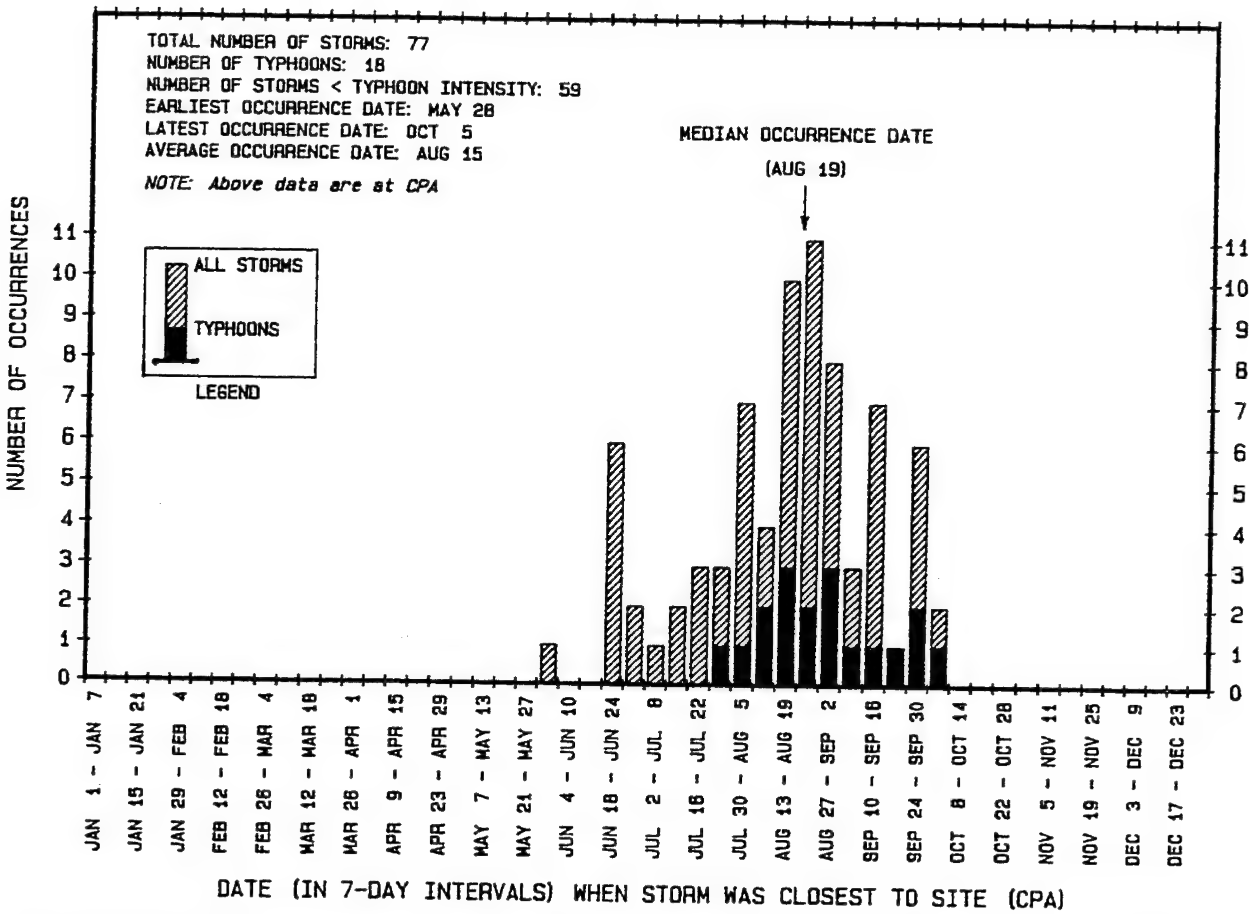

Figure VII-17. Monthly distribution of the 77 tropical storms or typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992.

Figure VII-18 depicts the annual distribution of the 77 tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945 through 1992.

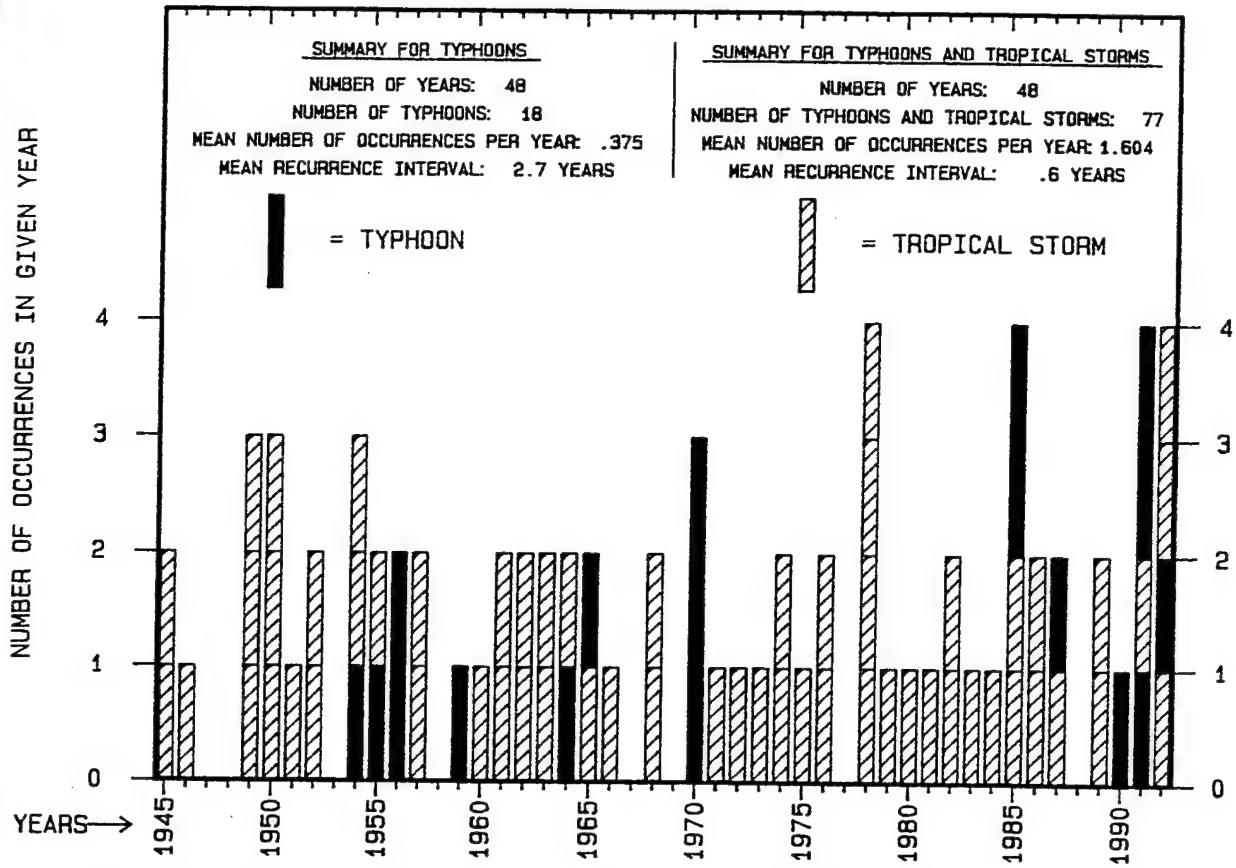

Figure VII-18. Chronology of the 77 tropical storms and typhoons passing within 180 nmi of Pusan during the 48-year period 1945-1992.

Figure VII-19 depicts, on an 8-point compass, the octants from which the 77 tropical cyclones in the data set approached Pusan. Over 88% (68 of 77) of the storms approached Pusan from either the southwest (49%) or south (39%) octants. This is largely due to Korea's position relative to the primary tropical cyclone storm track discussed above, and Pusan's location just north of the primary storm recurvature area.

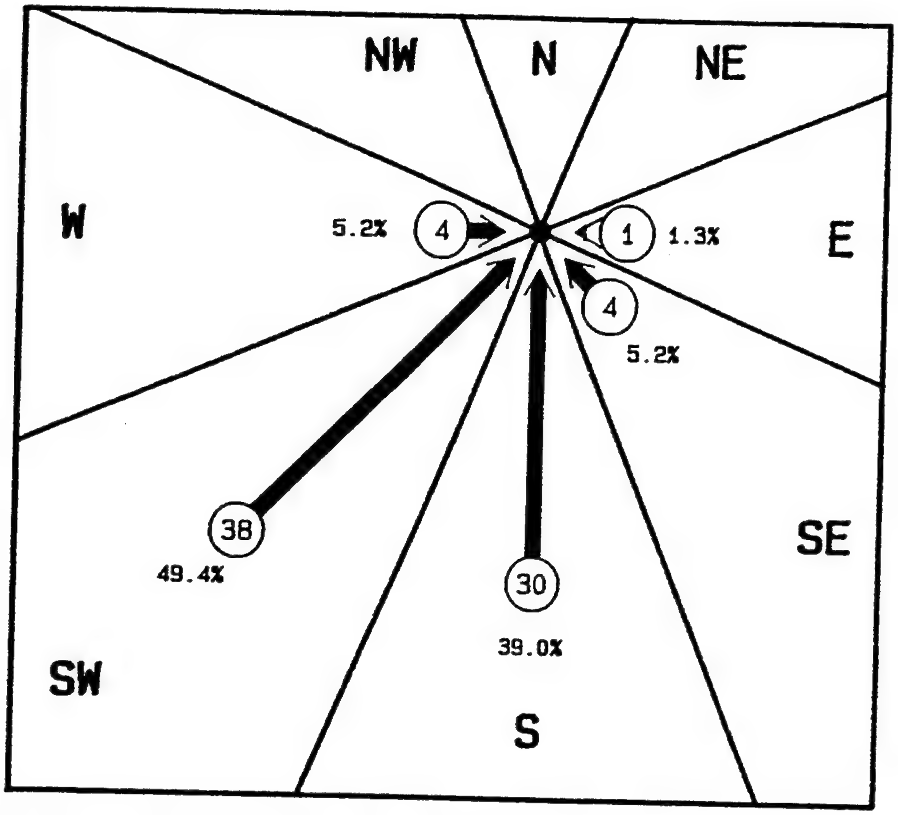

Figure VII-19. Directions of approach for the 77 tropical cyclones passing within 180 nmi of Pusan during the 48-year period of record.

Figures VII-20 and VII-21 provide information on the probability of remote tropical storms and/or typhoons passing within 180 nmi of Pusan and average time to CPA. The thinner lines represent a "percent threat" for any tropical cyclone location within the area depicted. The heavy, dashed lines represent the approximate time in days for a system to reach Pusan. For example, in Figure VII-20, during the months of July and August a tropical cyclone located at 25°N 135°E has an approximate 30% probability of passing within 180 nmi of Pusan and will reach Pusan in about 3 to 4 days.

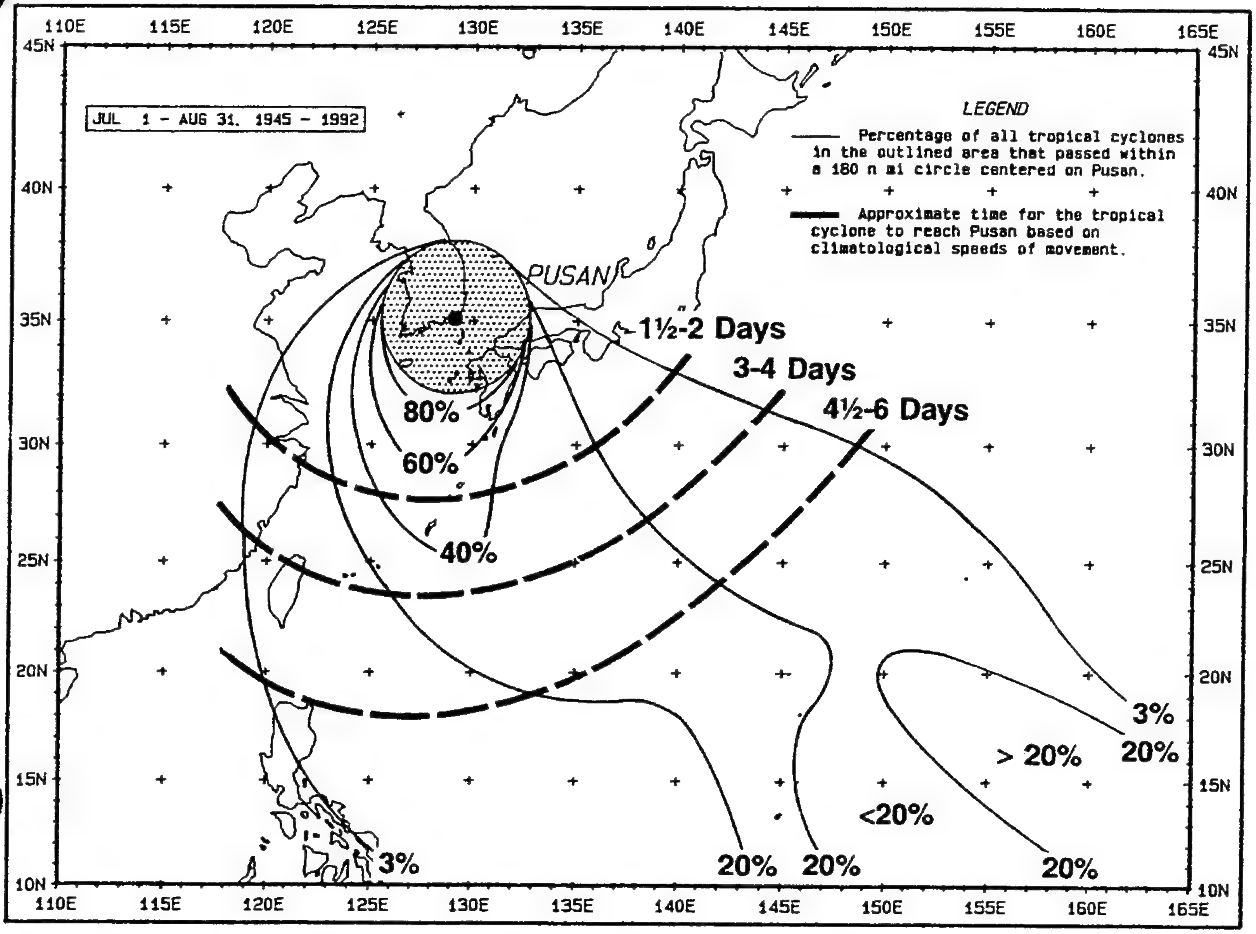

Figure VII-20. Probability that a tropical storm or typhoon will pass within 180 nmi of Pusan (circle), and approximate time to closest point of approach, during July and August.

A comparison of Figures VII-20 and VII-21 shows that there are distinct differences in threat axes according to the time of year. During July and August, the threat axis extends southward from Pusan to about 28°N before turning southeastward to the lower latitudes. The threat axis for the remainder of the year extends southwestward from Pusan to the southern Ryukyu Islands at about 25°N before turning southeastward.

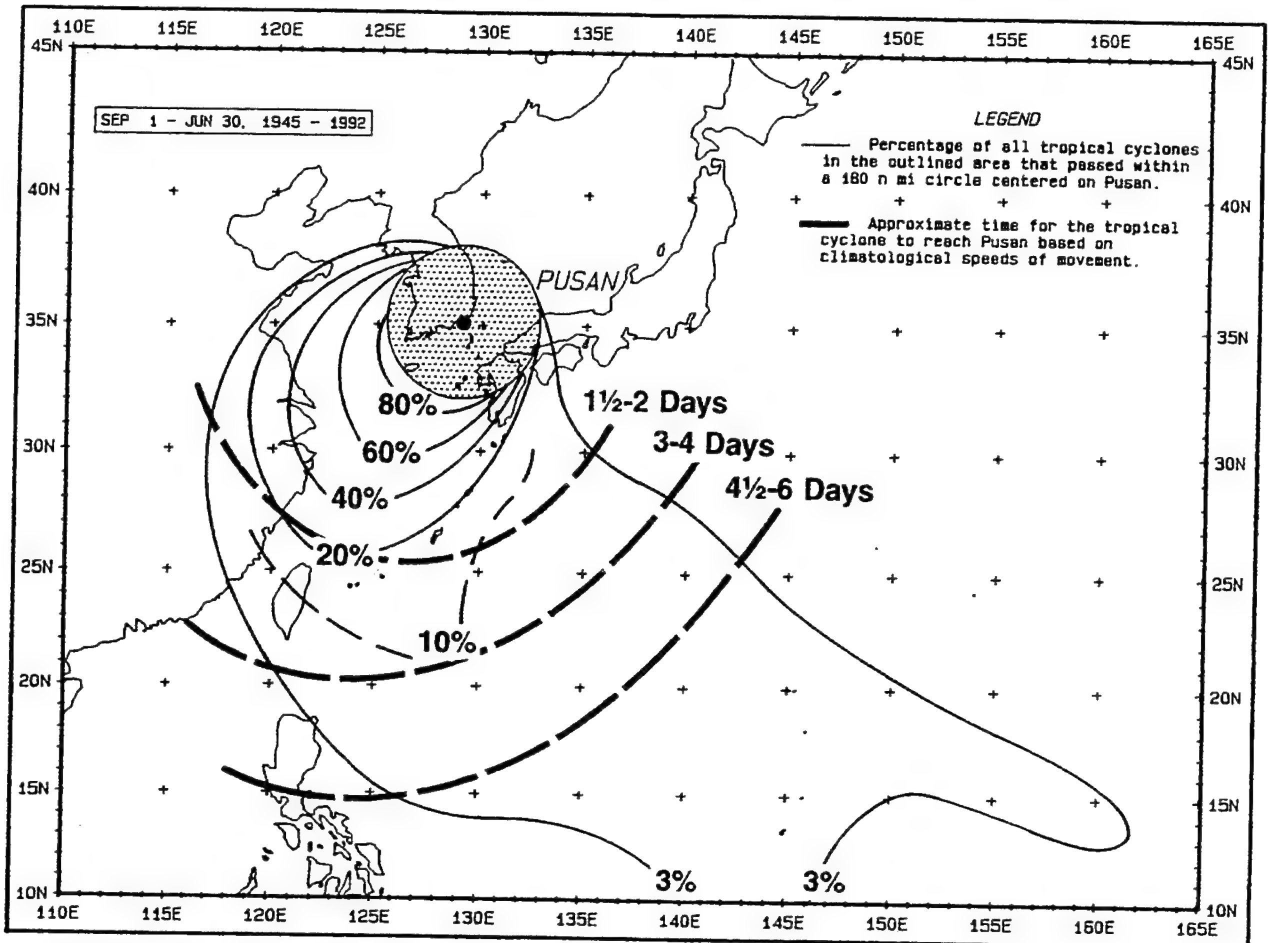

Figure VII-21. Probability that a tropical storm or typhoon will pass within 180 nmi of Pusan (circle), and approximate time to closest point of approach, during the period September through June.

3.5.2 Topographical Effects

The weather observation station for Pusan is located on an east-facing hillside on the west side of Pusan's North Inner Harbor (Figure VII-15). Local authorities state that winds observed at the station are not necessarily representative of those at the port because of the influence of the hills west and north of the station.

3.5.3 Local Weather Conditions

The data contained in Table VII-3 have been extracted from observations taken at Kimhae Air Base (35°11'N 128°56'E), located about 10 nmi northeast of Pusan, during the period 1973-1992.[1] No observations are available prior to 1973.

3.5.4 Wind

Whether or not a storm passes east or west of Pusan seems to make little difference as to the strength of the winds observed. Of the 15 storms detailed in Table VII-7 that caused winds of ≥22 kt at Pusan, 9 passed east of Pusan and 6 passed west. Of the 8 storms that caused winds of ≥34 kt, 5 passed east of Pusan and 3 passed west. The strongest winds observed at Pusan were caused by Typhoon Dinah which passed east of Pusan in 1987.

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[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

Table VII-7. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Pusan 1973-1992.

TROPICAL CYCLONE DATA				RELATED LOCAL WEATHER	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	WEATHER AND PRECIP. AMT/ ACCUM. PERIOD
73/08/17 (IRIS)	018/21	295/174	40	S 32G46	LIGHT RAIN 0.31"/24 HRS
74/07/06 (GILDA)	031/19	137/11	48	E 46	HEAVY RAIN 4.45"/24 HRS
76/09/12 (FRAN)	027/20	110/99	48	N 26G39	LIGHT RAIN
78/09/15 (IRMA)	064/18	150/100	43	N 25G39	RAIN 1.14"/24 HRS
79/08/17 (IRVING)	052/23	321/97	43	SE 40G59	HEAVY RAIN 2.83"/24 HRS
83/09/27 (FORREST)	076/30	165/139	63	ENE 34G52	RAIN 1.14"/24 HRS
84/08/20 (HOLLY)	045/17	150/33	58	ESE 40G60	RAIN SHOWERS
85/08/10 (KIT)	052/19	327/84	47	E 32G46	HEAVY RAIN
85/10/05 (BRENDA)	042/26	214/94	65	NE 39G58	HEAVY RAIN
86/06/25 (NANCY)	044/30	143/45	45	S 30G40	HEAVY RAIN
86/08/28 (VERA)	029/17	301/131	53	S 45G68	LIGHT RAIN
87/07/15 (THELMA)	018/25	295/74	63	ESE 35G60	HEAVY RAIN
87/08/30 (DINAH)	033/33	118/21	72	NE 48G74	HEAVY THUNDER-SHOWERS
98/07/28 (JUDY)	336/15	248/77	50	E 28G44	HEAVY THUNDER-SHOWERS
91/07/29 (CAITLIN)	037/19	125/31	72	ENE 32G46	RAIN

The beginning and end points of the arrows in Figure VII-22 give the positions of tropical cyclone centers when sustained winds ≥22 kt began and ended at Pusan (Kimhae Air Base) for 14 of the 36 tropical cyclones that passed within 180 nmi during the period 1973-1992. A fifteenth storm is not included in the figure because of the brevity of the 22 kt winds and the inability to depict an adequate track segment. Similarly, Figure VII-23 shows the positions of the centers of the 8 tropical cyclones that brought sustained winds of ≥34 kt to Pusan (Kimhae Air Base) for the same period. Dots at the end of the tracks indicate that the sustained winds at Pusan continued beyond the time of the solid track segment shown.

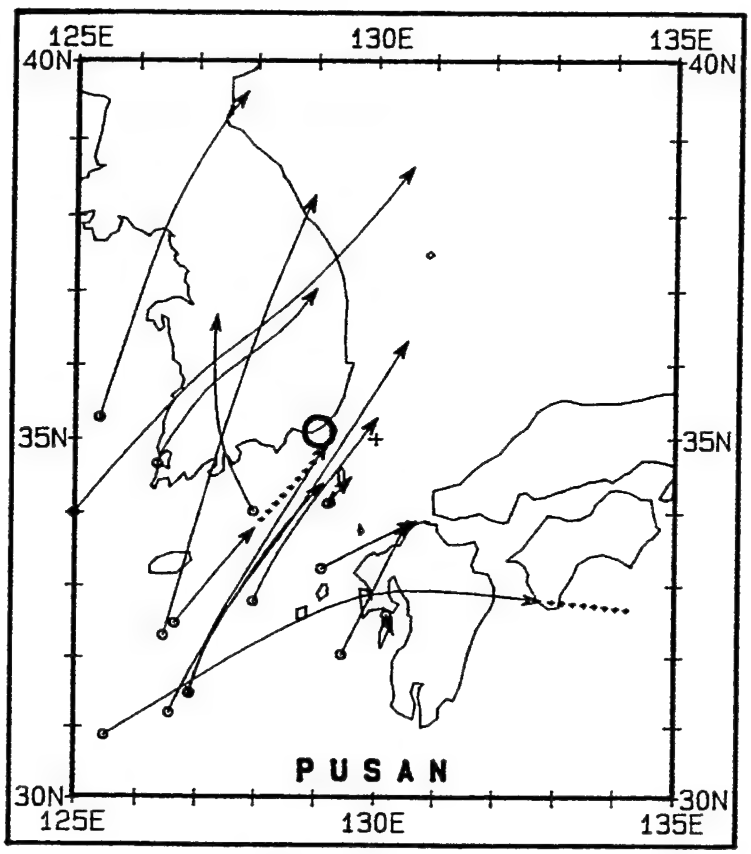


Figure VII-22. Track segments of the 14 tropical storms or typhoons causing sustained winds of at least 22 kt at Pusan during the period 1973-1992.

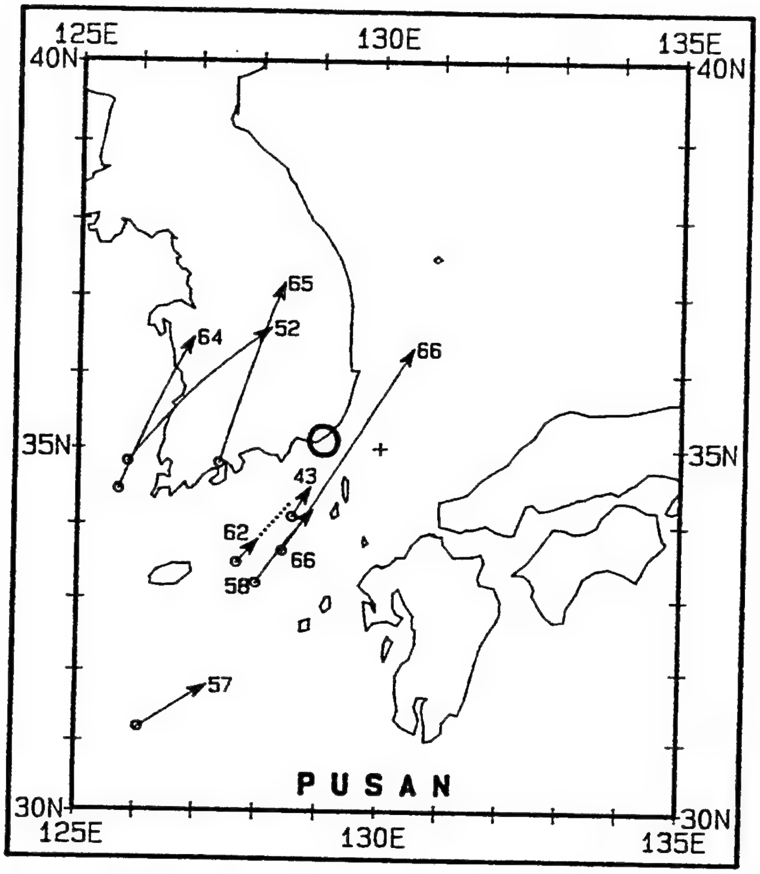


Figure VII-23. Track segments of the eight tropical storms or typhoons causing sustained winds of at least 34 kt at Pusan during the period 1973-1992. Numbers adjacent to track arrowheads correspond to storm index numbers listed in Table VII-5.

3.5.5 Wave Motion

The maximum wave heights that can be expected with typhoon strength winds (≥64 kt) in Pusan's North Harbor are given in Table VII-8. This information has been extracted from a prior evaluation of the Port of Pusan.

Table VII-8. Maximum wave heights that can be expected with typhoon strength winds ($\geq$64 kt) in the North Outer Harbor and North Inner Harbor at Pusan.

Location	North Outer Harbor	North Inner Harbor
Winds generally from the north (tropical cyclone passage east of Pusan)	4 ft	5 ft
Winds generally from the south (tropical cyclone passage west of Pusan)	12 ft	4 ft

As Table VII-8 indicates, wave motion in the North Inner Harbor is limited due to the short fetch. However, the North Outer Harbor has a limited fetch only for northerly winds; south to southeasterly winds can bring waves as high as 12 ft to the harbor due to the long fetch south of the harbor.

The wave heights presented in Table VII-8 are intended as a guide only. Specific storms may generate waves that vary from those listed in the table.

3.5.6 Storm Surge and Tides

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

The North Harbor at Pusan is susceptible to storm surge when the area experiences prolonged southerly winds of ≥35 kt. Past occurrences have resulted in increased water levels of up to 10 ft (3 m). A previous evaluation mentioned serious damage that resulted from Typhoon Sarah as the storm moved onshore just west of Pusan in September 1959. Typhoon Sarah had center winds of 98 kt and was moving 034° 24 kt when at its CPA to Pusan of 319° 12 nmi.

3.6 THE DECISION TO EVADE OR REMAIN IN PORT

3.6.1 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the NPMOCW/JTWC Guam Tropical Cyclone Warnings, and a basic understanding of weather will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures VII-20 and VII-21, discussed earlier, address the probability of existing tropical cyclones later affecting Pusan. As a further aid for the commander to evaluate a given situation, Figures VII-24 and VII-25 have been prepared. In contrast to Figures VII-20 and VII-21, Figures VII-24 and VII-25 consider only those storms which later passed within 180 nmi of Pusan. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing

arcs can be considered as an <u>average</u> approach scenario insofar as Pusan is concerned. It must be stressed that the other 50% of the storms which later affect Pusan will be <u>outside</u> of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures VII-24 and VII-25.

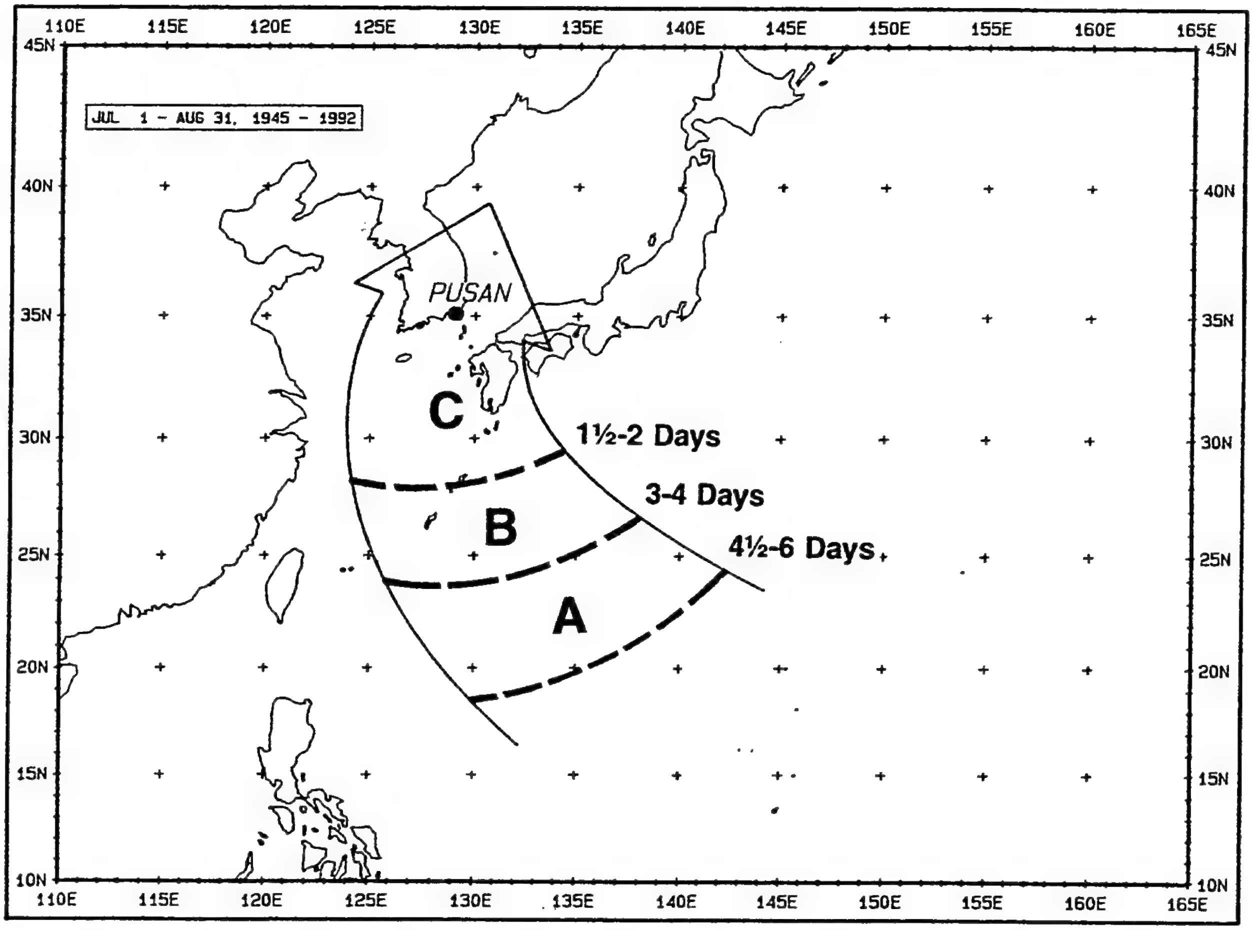


Figure VII-24. For the tropical cyclones passing within 180 nmi of Pusan during July and August, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Pusan. See Figure VII-20 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Pusan.

PUSAN

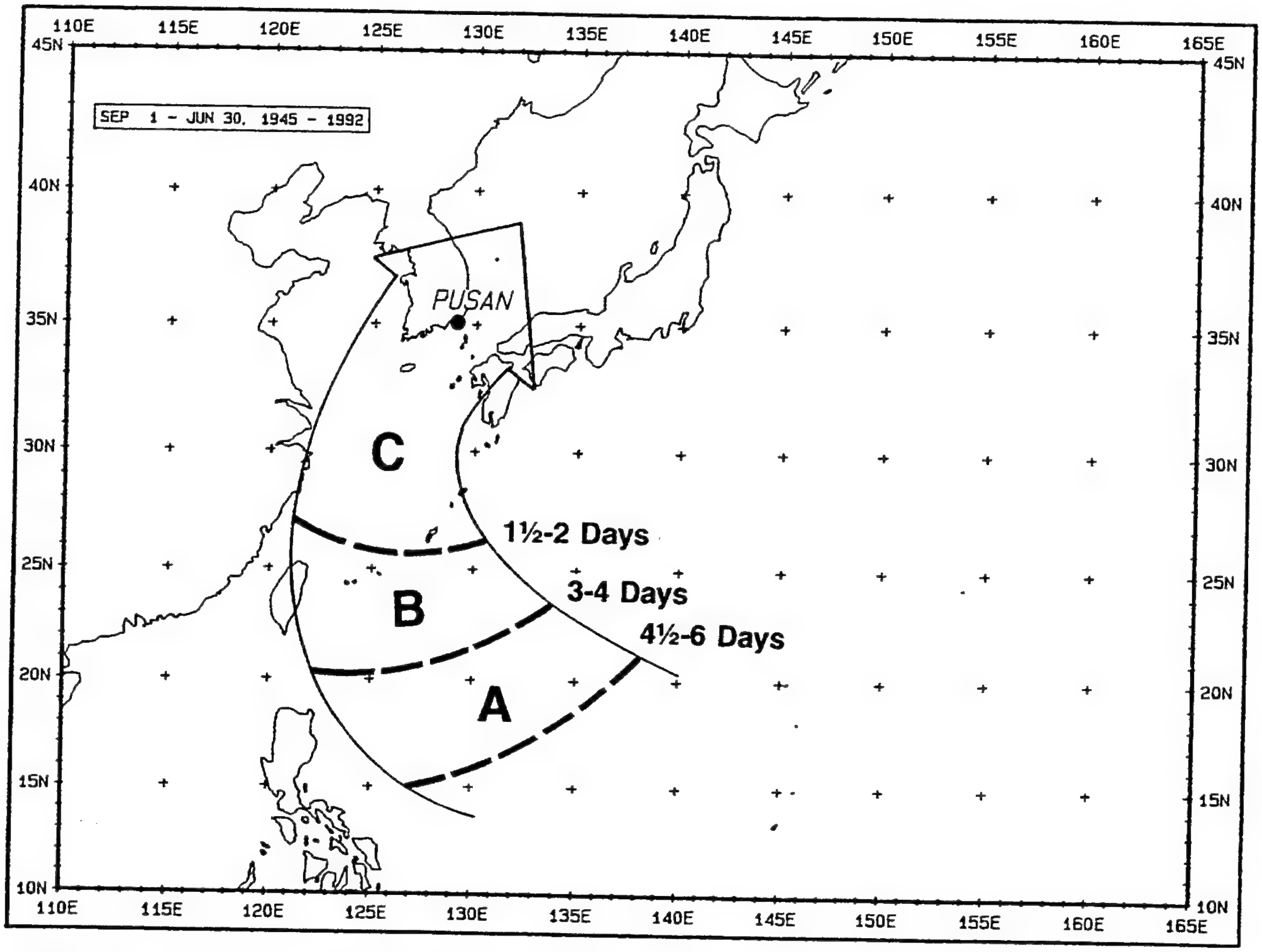


Figure VII-25. For the tropical cyclones passing within 180 nmi of Pusan during the period September through June, approximately 50% follow a track within the bounds of the arrow. However, not all storms that at some time are within these bounds pass within 180 nmi of Pusan. See Figure VII-21 for the areal pattern of actual probability of tropical cyclones passing within 180 nmi of Pusan.

The following time/action sequence, to be used in conjunction with Figures VII-24 and VII-25, has been prepared to aid the commander in planning ship operations.

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

a. Review material condition of ship. A sortie may be necessary in 48 hours.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters area B with forecast movement toward Pusan (recall that tropical cyclones tend to accelerate rapidly after they have recurved):

a. Operational plans should be made in the event of a sortie.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone enters area C moving toward Pusan:

a. Execute evasion plans made in previous steps.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

3.6.2 Remaining in Port

Pusan is not considered to be an adequate haven for U. S. Navy ships in a tropical cyclone situation. The reasons for not remaining in port include:

(1) The lack of protection from wind in the harbor,

(2) The vulnerability of Pusan harbor to storm surge, and

(3) The close proximity of Chinhae Bay, a highly regarded typhoon haven.

All U. S. Navy ships capable of getting underway should sortie from the port if Pusan is threatened by a tropical cyclone. For those vessels moored to Pier 8 and incapable of getting underway due to mechanical problems, the following precautions are recommended.

(1) All items capable of becoming flying projectiles in a strong wind should be removed or otherwise secured.

(2) Extra attention should be given to the mooring lines and to the brow during the passage of the storm. Crews should have extra line and wire available and be ready to tend lines during the storm's passage.

3.6.3 Evasion

Evasion from Pusan Harbor is the recommended course of action for all U. S. Navy ships. Evasion to the Yellow Sea or the Sea of Japan are the open ocean sortie options available; the choice will depend on the strength and forecast track of the approaching storm and how early in the planning process the sortie decision is made.

If moving into the Sea of Japan is considered, the commander must be aware that the ship may be placed in the stronger, and therefore more dangerous, semicircle (the right side of the storm

with respect to the storm's direction of movement). If a Sea of Japan sortie is ultimately chosen, possible havens include the Port of Maizuru (35°29'N 135°23'E), which offers excellent protection for small- to medium-sized vessels in tropical cyclone threat situations.

If remaining in Korean waters is preferred to evading at sea, moving to and anchoring in nearby Chinhae Bay (35°02'N 128°35'E) is an option that should be considered. Chinhae Bay is highly regarded as a good haven in all but the strongest tropical cyclone situations.

Whichever option is chosen, ship captains should remember that tropical cyclones are historically unpredictable, especially in the recurvature phase. The 48-hour forecast position error may exceed 200 nmi. Consequently, the storm may be closer to or farther from Pusan than the forecast indicates, or be right or left of its forecast track.

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with LCDR T. Knowles, USN, QMC M. T. Miller, USN and Mr. Hae-il Cho, of Port Operations, Commander Fleet Activities, Chinhae and Mr. Chang Hwan Yun, Supervisor and Marine Cargo Specialist of the U. S. Military Sealift Command, Pusan to obtain much of the information contained in this port evaluation.

REFERENCES

FICPAC, 1990: Port Directory for Pusan South Korea, Change 13. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Nestor, W. J. R., 1977: The Environment of South Korea and Adjacent Sea Areas. NAVENVPREDRSCHFAC Technical Report No. 77-03. Published by Naval Research Laboratory (formerly Naval Environmental Prediction Research Facility), Monterey, CA 93943.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

4. CHINHAE

SUMMARY

The conclusion reached in this study is that Chinhae Harbor can be considered a typhoon haven with the following considerations:

Ships of AEGIS cruiser size or larger with similar large sail areas should sortie under any tropical cyclone threat.

If maximum sustained winds at Chinhae are forecast to be 80 kt or less, destroyer-sized or smaller ships may remain in port. Larger vessels should seek shelter in Chinhae Bay.

If maximum sustained winds of 80 to 110 kt are forecast for Chinhae, destroyer-sized or smaller ships should also seek shelter in Chinhae Bay.

If the tropical cyclone is forecast to cause maximum sustained winds greater than 110 kt at Chinhae, a sortie is recommended for all ships. Two primary evasion routes are available, one to the Yellow Sea and the other to the Sea of Japan. The choice will depend on when the sortie decision is made and the forecast track of the tropical storm.

4.1 LOCATION

The Port of Chinhae is located in Chinhae Harbor on the southeast coast of the Republic of Korea at 35°08'N 128°38'E (Figure VII-26). The Port is approximately 22 nmi west of the much larger and busier port of Pusan.

In addition to being the site of the United States Navy command of Commander Fleet Activities (COMFLEACTS), Chinhae is also the principal Naval Base of the Republic of Korea (ROK) fleet.

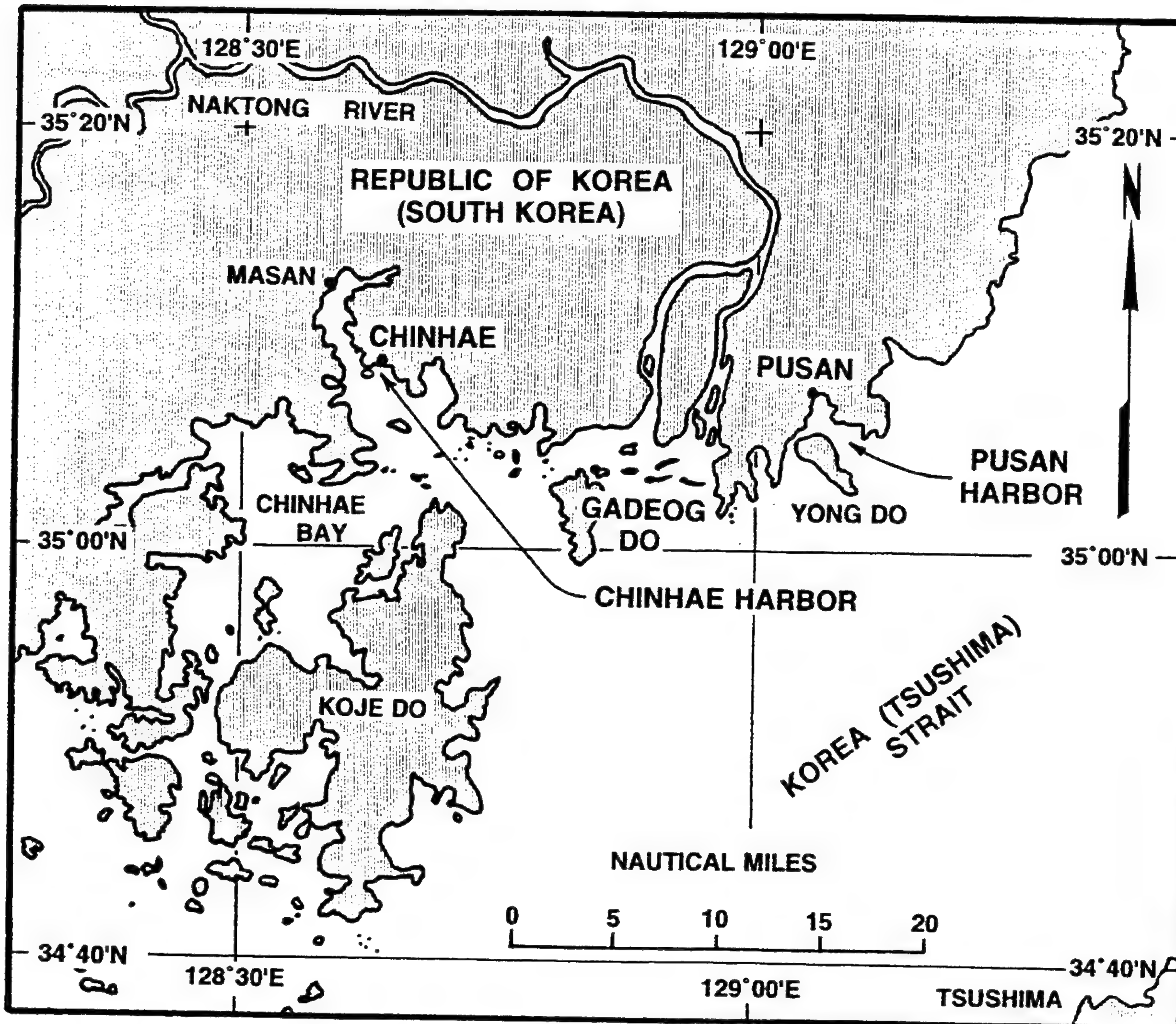


Figure VII-26. Location of Chinhae on the southeastern coast of the Korean Peninsula.

4.2 CHINHAE HARBOR AND APPROACHES

The harbor is entered from the southeast through Gadeog Channel (Figure VII-27). The channel varies in width from 2,600 yd at its seaward entrance to 1,000 yd where it splits just north of Koje Do (Island). The channel is reported to be difficult to navigate in strong winds due to shoal water between

Pu Do and Kureisser Cho (Rock). Because of the shoal water, large ships (≥28 ft draft) enter the harbor through a relatively narrow passage between Kureisser Cho and a promontory just to the west-northwest. When using this passage, there is a danger of being forced onto the rocks of the promontory during periods of strong northerly flow. Therefore, local port authorities recommend that large vessels not try to enter the port during strong northerly winds.

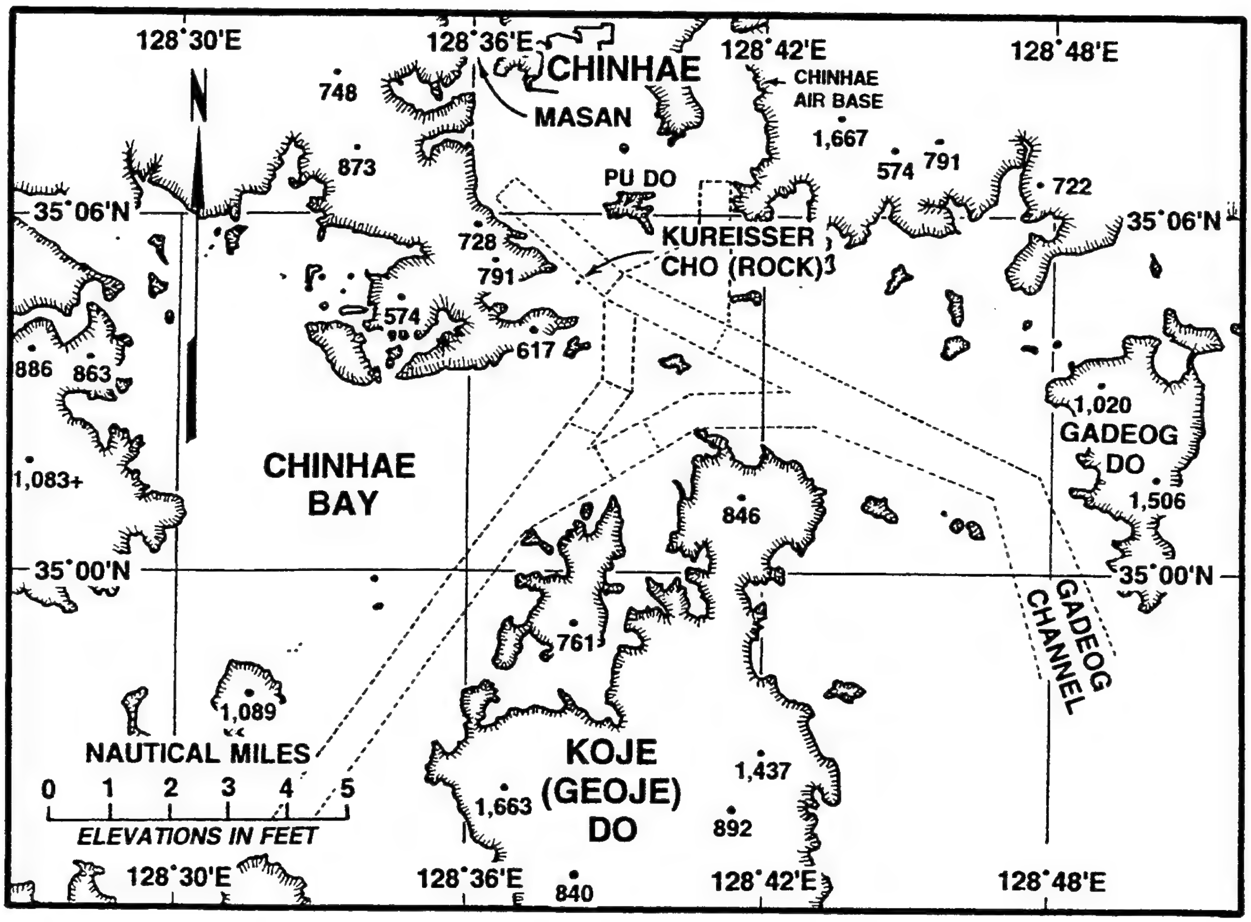


Figure VII-27. Approaches to Chinhae harbor.

The harbor has several piers and quays that are used by the ROK Navy. The ROK Navy is also the coordinating authority for

pier usage at the port. When U. S. Navy surface vessels visit the port and do not anchor, they are usually assigned to berth at Pier 9 (Figure VII-28). Only the south 700 ft of Pier 9 is considered usable by local U. S. Navy authorities because of suspected shoal water (depths less than 13 ft (4 m)) about 800 ft from the south end of the pier.

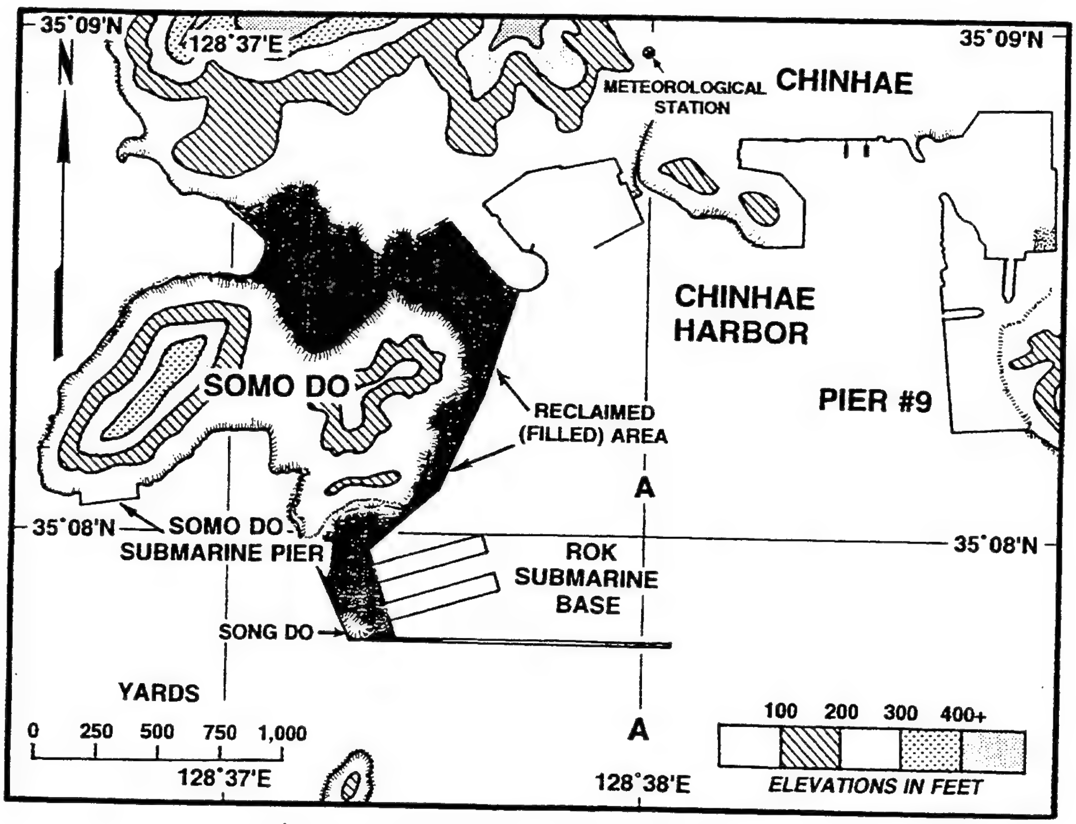


Figure VII-28. Chinhae Harbor.

Submarines moor to the pier on Somo Do. FICPAC (1990) states that some surface ships have also moored at Somo Do, and

noted greater alongside depths than Pier 9. Only one vessel of any type can be accommodated at Somo Do at any one time because nesting is not permitted.

As of September 1993, the ROK Navy was constructing a submarine base in Chinhae Harbor. The location is shown on Figure VII-28, with the approximate outline of the pier facilities indicated. The exact configuration is not known because pier construction was just being started at the time of the port visit (Sep 1993).

Extensive filling has been completed on the north, east, and south sides of Somo Do. Because of the filling, Somo Do is in reality no longer an island; it is now connected to the mainland.

When construction is completed, the new submarine facility should afford excellent protection to moored submarines from winds and seas from southeast clockwise through west. In addition to its protected location, the design of the facility is unique because the builders have erected two wind fences to protect the submarine piers from strong winds. One, oriented east-west on the western half of the newly constructed breakwater is located just south of the piers. The other is oriented north-northwest to south-southeast near the west end of the piers. It is located across the filled area between Somo Do and what used to be (before filling connected it to Somo Do) the small island of Song Do to the south. Each fence is estimated to be 32-38 ft (10-12 m) high, and is constructed of steel vertical supports and fixed, horizontal, sturdy, fiberglass panels. The panels are mounted venetian blind-style so that any wind impacting the fences from south through west will be deflected upward before reaching the piers. Although southerly through westerly winds will undoubtedly reach the pier area, the horizontal wind force

should be significantly diminished by the deflecting effect of the wind fences.

Several anchorages are available in the harbor. The designated nuclear anchorage for U. S. Navy ships is now bisected by the long, east-west breakwater that was constructed just south of the new ROK submarine base. The anchorage now has portions north and south of the breakwater. The approximate central location of each section is indicated by the letters "A" on Figure VII-28. By OPNAV instruction, the designated anchorage is the only anchorage nuclear ships may use. Due to the restricted size of the southern segment, nuclear ships are now limited to using the northern section. However, a potentially hazardous situation exists for ships using the northern section in northerly wind situations. If anchor dragging occurred, the ship would be forced toward the breakwater. Consequently, local port authorities recommend that ships not use the anchorage if a tropical cyclone is forecast to pass east of the port and bring northerly winds to the port area.

The bottom of the northern portion is mud with good holding in water depths of 29.5 to 36 ft (9 to 11 m). The bottom type and holding quality of the southern section is unspecified, but water depths range from 38 to 41 ft (11.5 to 12.5 m).

Several mooring buoys are located in the anchorages. The largest buoys in the northern part are secured to 10-ton concrete blocks as well as having an anchor line attached to a navy anchor. The smaller buoys have 6-ton blocks, also with an anchor line. Local personnel state that the safest buoys for small ships to use are buoys 5 and 8. Note: According to local personnel the buoys were moved during the ROK Submarine Base construction. Consequently, buoy positions marked on harbor charts may not be accurate.

A large anchorage is located in the southern portion of Chinhae Harbor. A total of 18 anchorage positions, designated Y-1 through Y-18, are identified (Figure VII-29). Large U. S. Navy vessels are usually assigned to positions Y-1 or Y-2.

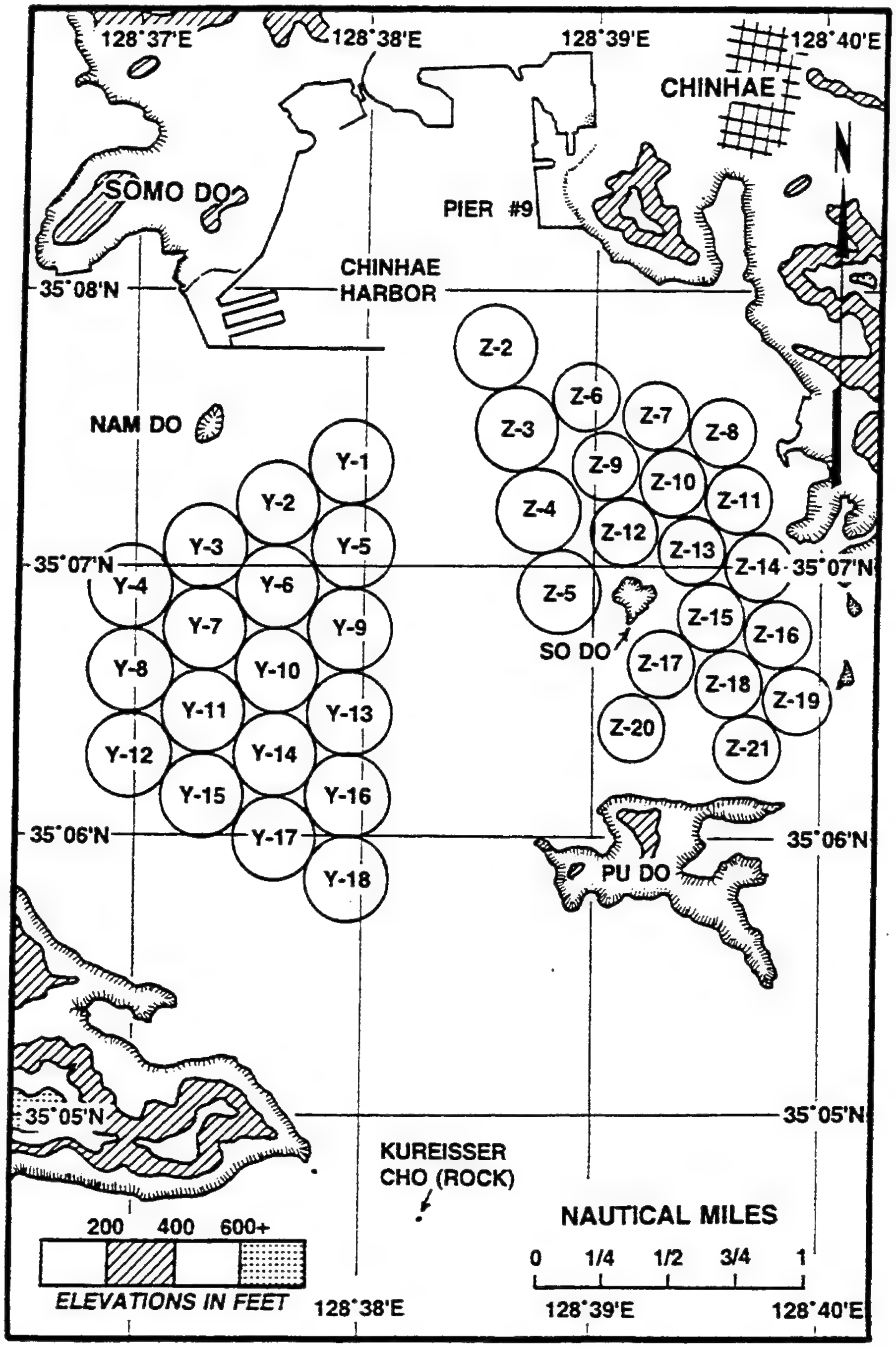


Figure VII-29. Anchorages in Chinhae Harbor.

A second large anchorage, also shown on Figure VII-29, is located in the southeast part of Chinhae Harbor, and is normally used by ROK Navy vessels. A total of 20 anchorage positions, designated Z-2 through Z-21, are identified.

Tidal range is normally about 6 ft, with a 7-ft extreme tide occasionally observed. Currents in the harbor are minimal.

4.3 HARBOR FACILITIES

Piers at Chinhae are in good repair. A total of seven non-floodable Yokohama fenders are available for use by U. S. Navy ships: four with diameters of 4.9 ft (1.5 m) and three with diameters of 8.2 ft (2.5 m). In addition, two vertical, rubber fenders are available for use by submarines at the Somo Do pier. Each is 25 ft (7.6 m) long, with 8 ft (2.4 m) extending above the water surface.

The harbor has two dry docks, neither of which is used by U.S. Navy ships. In addition, one 50-ton and two 30-ton floating cranes, as well as 15- and 20-ton mobile cranes are available for service to visiting ships. Tug boats are available, but operate out of Masan (Figures VII-26 and VII-27). Advance notice of requirements at Chinhae is necessary because it is a 40-minute run from Masan to Chinhae. Pilotage is mandatory in Chinhae Harbor.

4.4 TOPOGRAPHY

Chinhae harbor is well protected by hills in all directions except southeast (Nestor, 1977). The rugged topography of the Korean Peninsula, with elevations commonly exceeding 1,640 ft (500 m), reduces any wind flow from southwest clockwise through east. The relatively large island of Koje Do (spelled Goeje Do

on some documents), located approximately 8 nmi south of the inner harbor (Figure VII-27), provides limited protection from wind and good protection from waves from the south. Koje Do has elevations commonly exceeding 820 ft (250 m) and individual peaks exceeding 1,640 ft (500 m).

4.5 TROPICAL CYCLONES AFFECTING CHINHAE

4.5.1 Tropical Cyclone Climatology at Chinhae

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Chinhae is considered to represent a threat to the port. Table VII-9 contains a descriptive history of all 74 tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992. All of the tropical cyclone statistics used in this report for storms passing within 180 nmi of Chinhae are based on the data set used to compile Table VII-9.

CHINHAE

Table VII-9. Descriptive history of all tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	EVA	1945	AUG	4	9	40	81 (W)	360/26.0
2	URSULA	1945	SEP	13	17	43	90 (NNW)	058/23.5
3	LILLY	1946	AUG	20	8	44*	31 (WSW)	336/ 8.5
4	DELLA	1949	JUN	21	2	50	121 (E)	001/11.5
5	FAYE	1949	JUL	18	4	43*	92 (E)	011/ 8.2
6	JUDITH	1949	AUG	17	8	30	58 (SE)	049/ 2.8
7	ELSIE	1950	JUN	24	3	55	66 (SE)	035/38.2
8	GRACE	1950	JUL	21	5	34	80 (W)	360/12.2
9	KEZIA	1950	SEP	13	9	51	121 (ESE)	007/26.1
10	MARGE	1951	AUG	23	7	48	113 (WNW)	021/21.3
11	KAREN	1952	AUG	18	8	56	115 (NW)	033/23.3
12	MARY	1952	SEP	3	10	45	138 (NW)	038/37.3
13	GRACE	1954	AUG	18	4	65	180 (SE)	041/10.4
14	KATHY	1954	SEP	7	9	50	151 (ESE)	014/21.4
15	JUNE	1954	SEP	13	10	68	150 (ESE)	012/27.6
16	LOUISE	1955	SEP	30	15	82	136 (E)	012/26.4
17	BABS	1956	AUG	16	9	80	101 (SE)	051/20.4
18	EMMA	1956	SEP	9	12	103	48 (ESE)	030/28.6
19	VIRGINIA	1957	JUN	27	5	50	104 (SSE)	074/34.0
20	AGNES	1957	AUG	21	7	45	29 (W)	005/25.1
21	SARAH	1959	SEP	17	14	98	13 (S)	032/24.7
22	CARMEN	1960	AUG	22	14	46	151 (WNW)	022/25.9
23	BETTY	1961	MAY	28	6	36	11 (W)	061/32.8
24	HELEN	1961	AUG	2	12	40	40 (WSW)	346/10.3
25	JOAN	1962	JUL	10	5	40	121 (WNW)	030/26.3
26	AMY	1962	SEP	7	17	34	178 (NNW)	058/36.0
27	SHIRLEY	1963	JUN	19	4	55*	32 (WNW)	044/29.3
28	BESS	1963	AUG	10	9	38	93 (E)	360/ 8.3
29	HELEN	1964	AUG	2	11	73	135 (WSW)	327/12.0
30	KATHY	1964	AUG	24	15	60	174 (ESE)	034/11.7
31	DINAH	1965	JUN	20	10	35	171 (ESE)	026/24.4
32	JEAN	1965	AUG	6	16	79	142 (ESE)	030/23.7
33	BETTY	1966	AUG	30	16	30	68 (NW)	053/ 8.1
34	POLLY	1968	AUG	16	7	40	38 (SE)	041/28.4
35	DELLA	1968	SEP	25	15	35	157 (SE)	024/12.9
36	WILDA	1970	AUG	14	8	70	132 (ESE)	036/21.7
37	BILLIE	1970	AUG	30	10	70	153 (WSW)	340/10.1
38	OLIVE	1971	AUG	5	19	58*	87 (ESE)	017/17.5
39	RITA	1972	JUL	25	8	75	169 (WSW)	343/28.2
40	TESS	1972	JUL	23	10	44	105 (E)	002/20.1
41	IRIS	1973	AUG	17	10	42	153 (WNW)	018/21.0
42	GILDA	1974	JUL	6	9	48*	30 (ESE)	031/18.8
43	PHYLLIS	1975	AUG	17	7	42	89 (E)	345/ 8.1
44	THERESE	1976	JUL	19	9	47*	149 (SSE)	077/ 6.2
45	FRAN	1976	SEP	12	17	50	118 (ESE)	026/20.2
46	POLLY	1978	JUN	20	3	33	132 (SSE)	063/18.2
47	WENDY	1978	AUG	2	8	40	135 (SE)	024/16.9
48	CARMEN	1978	AUG	20	11	30	92 (WSW)	013/19.7
49	IRMA	1978	SEP	15	18	45	111 (SSE)	063/17.8
50	IRVING	1979	AUG	17	12	47*	84 (NW)	051/23.2
51	ORCHID	1980	SEP	11	17	53	154 (E)	012/30.7
52	OGDEN	1981	JUL	31	10	33	119 (WSW)	334/11.3
53	ELLIS	1982	AUG	27	14	48	167 (E)	358/21.0
54	FORREST	1983	SEP	28	11	63*	147 (SSE)	076/30.2
55	ALEX	1984	JUL	5	3	30	72 (WNW)	053/22.0
56	HOLLY	1984	AUG	21	11	58*	48 (SE)	045/17.3
57	KIT	1985	AUG	10	8	50*	70 (NW)	053/19.4
58	ODESSA	1985	AUG	31	12	45	92 (SE)	035/18.9
59	PAT	1985	AUG	31	13	78	93 (ESE)	018/23.9
60	BRENDA	1985	OCT	5	20	65	86 (SSW)	042/25.9

NOTES:

Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.1°N, 128.6°E.

Table VII-9 (continued). Descriptive history of all tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
61	NANCY	1986	JUN	25	5	45	61 (SE)	044/29.7
62	VERA	1986	AUG	28	14	55*	112 (WNW)	028/17.1
63	THELMA	1987	JUL	15	5	63*	55 (WNW)	018/25.4
64	DINAH	1987	AUG	30	11	72	41 (ESE)	033/33.3
65	ELLIS	1989	JUN	24	6	35	132 (ESE)	021/23.2
66	JUDY	1989	JUL	28	11	48*	59 (WSW)	342/17.8
67	CAITLIN	1991	JUL	29	9	73	49 (SE)	037/18.9
68	GLADYS	1991	AUG	23	14	40	63 (SW)	306/ 8.9
69	KINNA	1991	SEP	13	19	77	138 (ESE)	039/27.6
70	MIREILLE	1991	SEP	27	21	90	125 (SE)	042/38.9
71	IRVING	1992	AUG	5	10	25	24 (SE)	025/ 7.7
72	JANIS	1992	AUG	8	11	78	155 (SE)	040/17.7
73	KENT	1992	AUG	19	12	30	112 (E)	003/11.2
74	TED	1992	SEP	24	20	38	54 (NNW)	074/29.4

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 35.1°N, 128.6°E.

Tropical cyclones which affect Korea generally have the same genesis area as those affecting Japan: 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment. Most of the storms affecting Chinhae move northwestward from the genesis area to the East China Sea or western Philippine Sea south of the island of Kyushu, Japan before recurving north or northeastward to within 180 nmi of Chinhae.

An examination of Table VII-10 shows that June through September is the primary season for tropical cyclone activity at Chinhae, with 97% (72 of 74) occurring during that period. Of those, 86% (64 of 74) occurred from July through September. Although storms have occurred as early as May (one tropical storm on May 28th) and as late as October (one typhoon on October 5th), the overwhelming majority of the storms are confined to the June

through September period. August is the month of greatest activity, with 47% (35 of 74) occurring during that month. August is also the month of greatest threat from typhoon-strength storms, as it has 50% (9 of 18) of the total typhoon occurrences.

Table VII-10. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	1	8	12	35	17	1	0	0	74
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	2	9	6	1	0	0	18
Number of storms less than typhoon intensity at CPA	0	0	0	0	1	8	10	26	11	0	0	0	56
Average heading (degs) towards which storms were moving at CPA	—	—	—	—	*	038	015	017	036	*	—	—	025
Average storm speed (knots) at CPA	—	—	—	—	*	26	18	17	27	*	—	—	21
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

The average movement for the 74 storms affecting Chinhae is 025° 21 kt. Sixty-one of the 74 storms (82%) were moving in a direction toward the northeast quadrant when at CPA (indicating they had already recurved), three were moving due north, and 10 were moving toward the northwest quadrant.

During the 48-year period from 1945 through 1992 there were 74 tropical storms and typhoons that met the 180 nmi threat criterion for Chinhae, an average of approximately 1.5 per year. Figure VII-30 depicts the distribution of the 74 storms by 7-day periods. As can be seen in the figure, the period of significant activity extends from mid-June through September, but the period of peak activity occurs from mid-July through September.

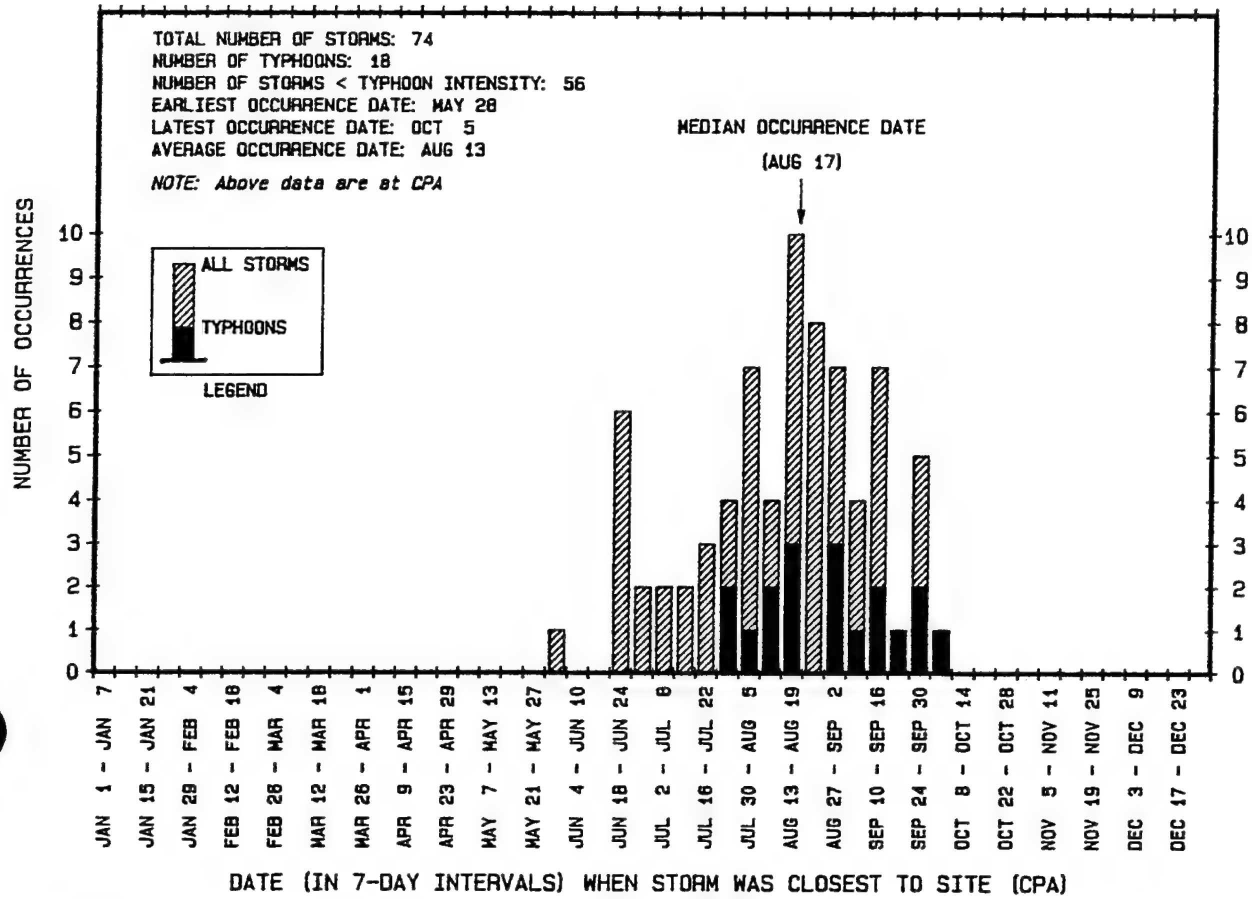


Figure VII-30. Monthly distribution of the 74 tropical storms or typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992.

Figure VII-31 depicts the annual distribution of the 74 tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945 through 1992. It can be seen in the figure that typhoon-strength storms (at CPA) are not as commonly seen at Chinhae as are tropical storm-strength storms, although 25% (12 of 48) of the years had typhoons enter the 180 nmi threat radius of the harbor. Of those, 42% (5 of 12) had multiple occurrences of typhoon-strength storms.

CHINHAE

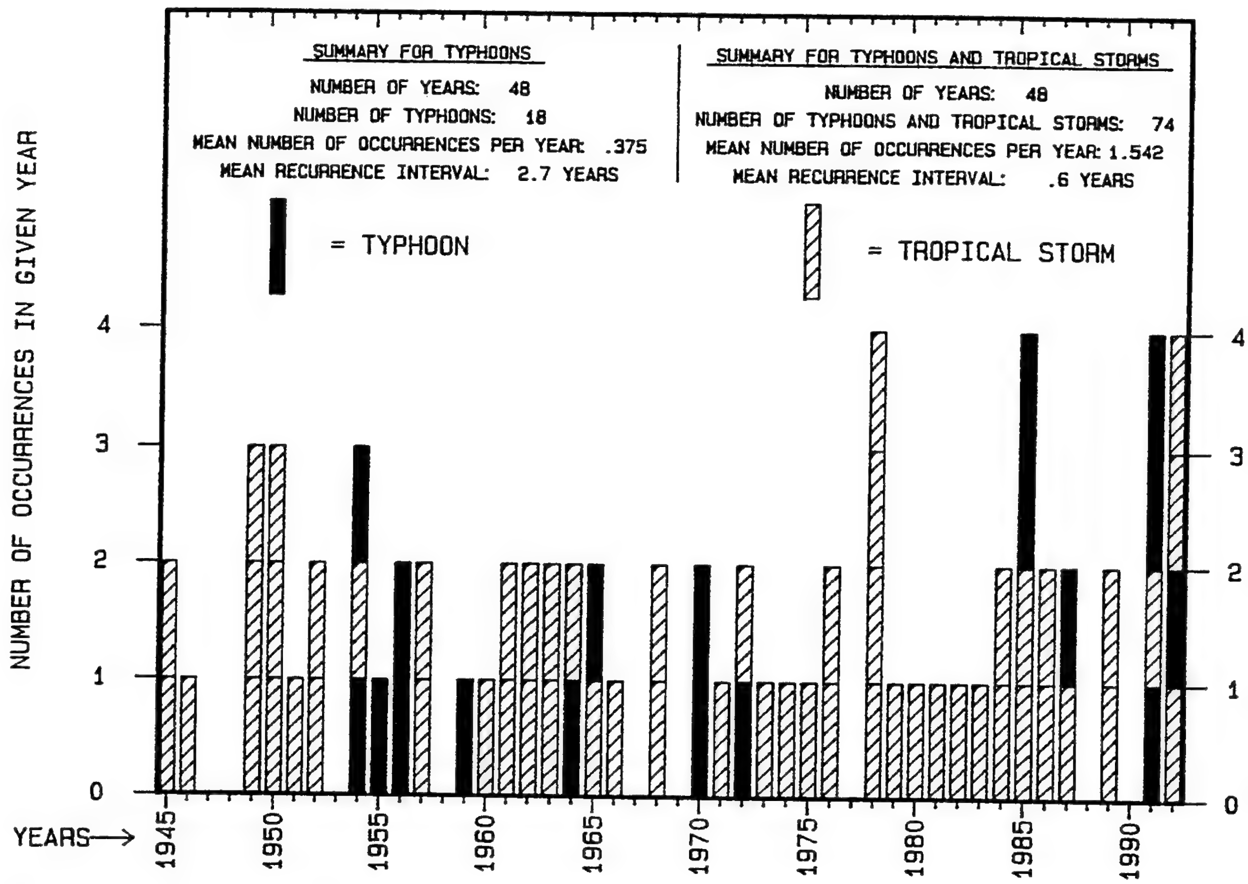


Figure VII-31. Chronology of the 74 tropical storms and typhoons passing within 180 nmi of Chinhae during the 48-year period 1945-1992.

Figure VII-32 depicts, on an 8-point compass, the octants from which the 74 tropical cyclones in the data set approached Chinhae. Over 89% (66 of 74) of the storms approached Chinhae from either the southwest (53%) or south (37%) octants. The predominance of these directions is largely due to Korea's position relative to the primary tropical cyclone storm track discussed above, and Chinhae's location just north of the primary storm recurvature area.

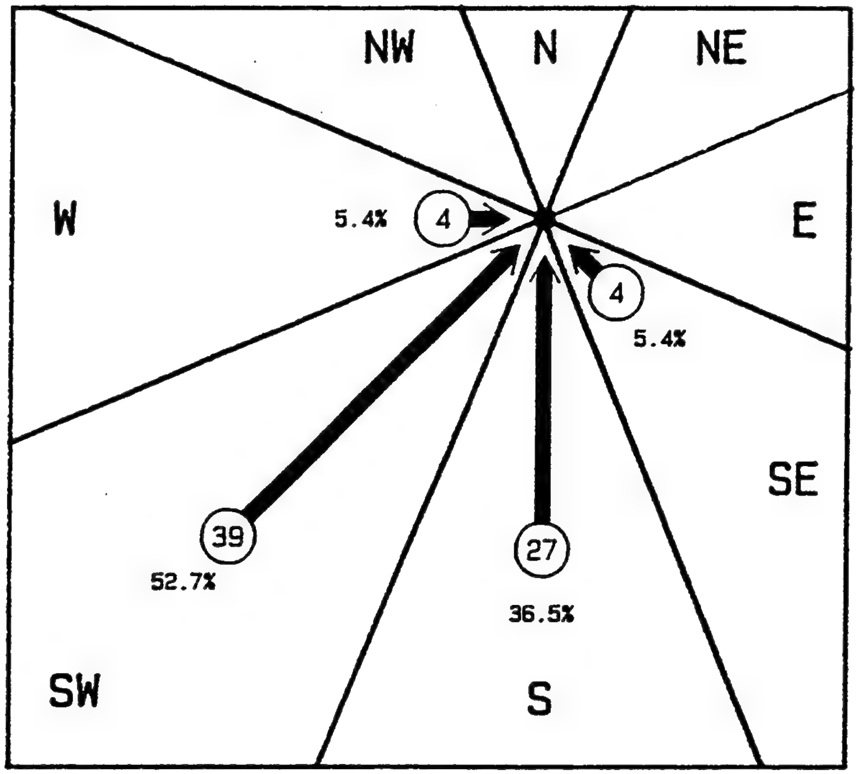


Figure VII-32. Directions of approach for the 74 tropical cyclones passing within 180 nmi of Chinhae during the 48-year period of record.

Figures VII-33 and VII-34 provide information on the probability of remote tropical storms and/or typhoons passing within 180 nmi of Chinhae and average time to CPA. The thin, solid lines represent a "percent threat" for any tropical cyclone location within the area depicted. The heavy, dashed lines represent the approximate time in days for a system to reach Chinhae. For example, in Figure VII-33, during the months of July and August a tropical cyclone located at 25°N 135°E has an approximate 25% probability of passing within 180 nmi of Chinhae and will reach Chinhae in about 3 to 4 days.

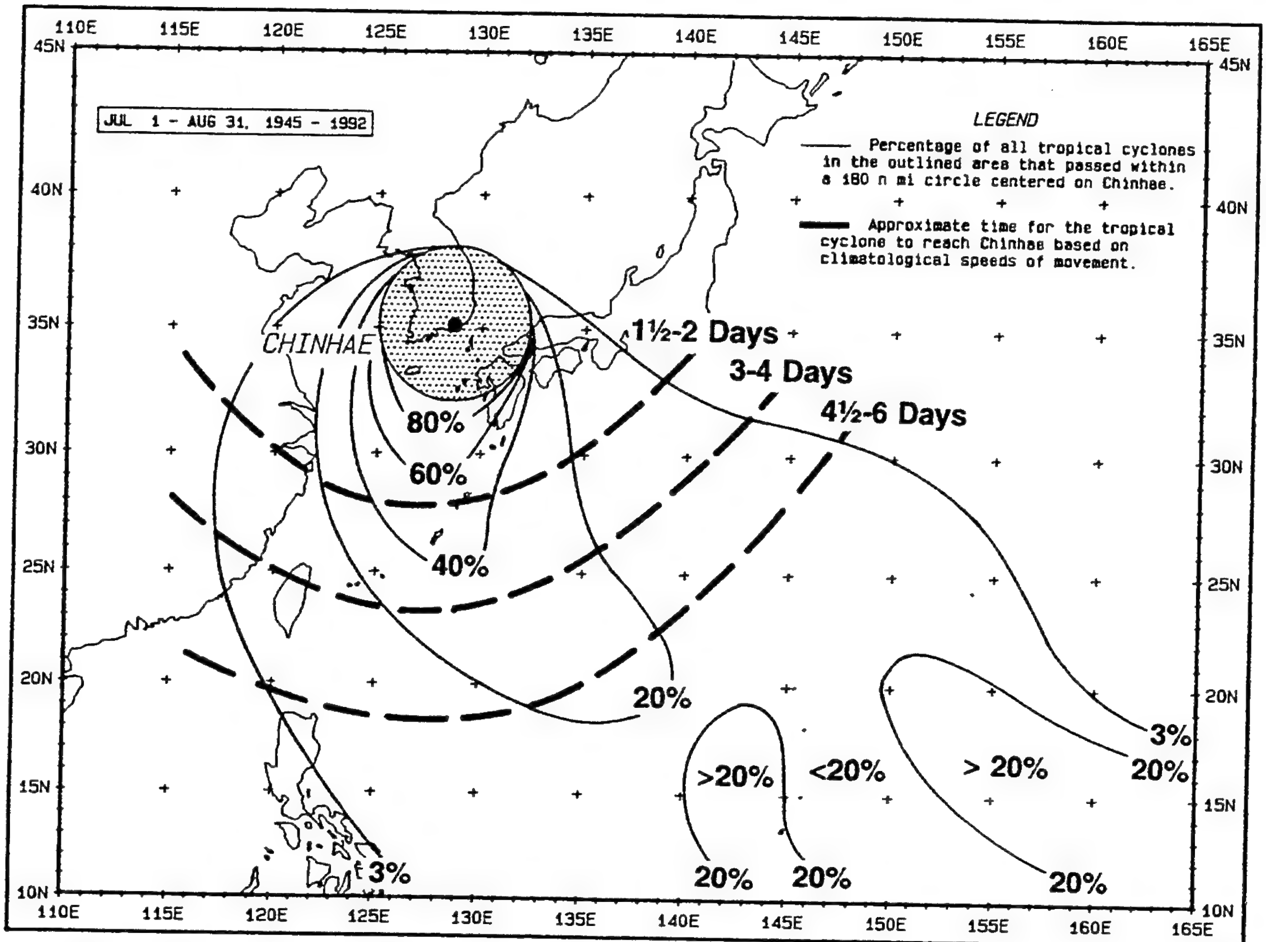


Figure VII-33. Probability that a tropical storm or typhoon will pass within 180 nmi of Chinhae (circle), and approximate time to closest point of approach, during July and August.

A comparison of Figures VII-33 and VII-34 shows that there is a significant difference in threat axes according to time of year. The months of July and August (Figure VII-33) have an axis that extends southward from Chinhae to about 28°N near the Ryukyu Islands before slowly turning southeastward to the more tropical latitudes. The threat axis for the period from September through June, however, extends southwestward from Chinhae to the east coast of the People's Republic of China at about 28°N before turning southeastward to the tropics.

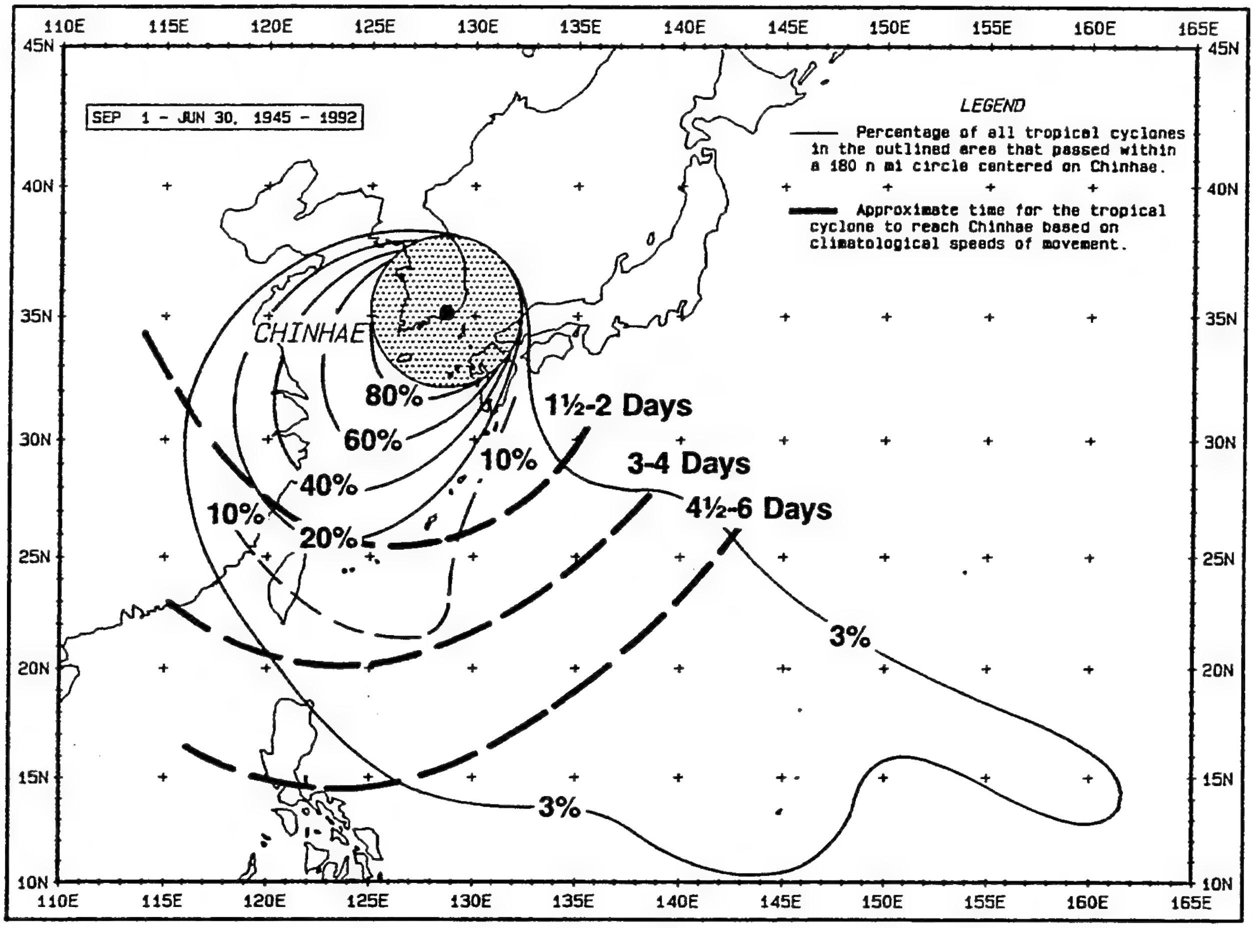


Figure VII-34. Probability that a tropical storm or typhoon will pass within 180 nmi of Chinhae (circle), and approximate time to closest point of approach, during the period September through June.

4.5.2 <u>Topographical Effects</u>

Chinhae's current meteorological observation station is located in the position indicated on Figure VII-28. Because of its location near adjacent hills west of the station and generally mountainous topography north of the port, local harbor personnel consider winds at the station to be representative only of southerly directions.

The mountainous terrain of southern Korea and the islands adjacent to Chinhae are considered to provide excellent protection to the port in all but the most severe tropical cyclone situations. However, a previous evaluation of Chinhae as a typhoon haven related what was described as "the only blemish on Chinhae Harbor's record as a typhoon haven". It occurred during the passage of Typhoon Sarah, which had a CPA 10 nmi south of Chinhae, with maximum center winds (at CPA) of 98 kt. The storm crossed the Korean coast between Chinhae and Pusan in 1959. The mountains surrounding Chinhae were effective in reducing the winds substantially (55 kt winds were reportedly observed from the northeast), but even so, several ROK Navy vessels were damaged when they ran aground. It should also be noted that some vessels ran aground because they were, reportedly, improperly anchored.

4.5.3 Local Weather Conditions

Naval Pacific Meteorology and Oceanography Facility (NPMOF) Yokosuka provides daily weather support to COMFLEACTS, Chinhae, and would provide meteorological support in addition to warnings from Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/JTWC) Guam in the event of tropical cyclone passage.

The data contained in Table VII-11 have been extracted from observations taken at Chinhae Air Base (35°08'N 128°42'E), during the period 1951-1954.[1] No observations are available during the periods 1945-1950 and 1955-1992.

[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

Table VII-11. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Chinhae 1951-1954. No other observational data are available for Chinhae.

TROPICAL CYCLONE DATA				RELATED LOCAL WEATHER	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	WEATHER AND PRECIP. AMT/ ACCUM. PERIOD
52/08/18 (KAREN)	033/23	307/115	56	SE 36G52	HEAVY RAIN 1.00"/24 HRS
52/09/03 (MARY)	038/37	311/138	45	SW 22G32	HEAVY RAIN 2.04"/24 HRS
54/08/17 (GRACE)	041/10	129/180	65	NE 24G35	LIGHT RAIN 0.06"/24 HRS

4.5.4 Wind

The paucity of data in Table VII-11 makes it difficult, based on those data alone, to accurately judge the effects on the harbor of storms passing west of Chinhae versus storms passing to the east. However, an examination of Figures VII-26 through VII-29 shows that southeast is the only direction open to the sea from Chinhae. The remainder of the directions, from south clockwise through east, have significant topographical barriers to wind flow. Consequently, any storm passing west of the harbor would normally pose the greatest wind threat to Chinhae. It should be noted that one exception to this thesis is discussed in Section 4.5.2 above.

The beginning and end points of the arrows in Figure VII-35 give the positions of tropical cyclone centers when sustained winds of ≥22 kt began and ended at Chinhae Air Base for 3 of the tropical cyclones that passed within 180 nmi of Chinhae during the period 1951-1954.

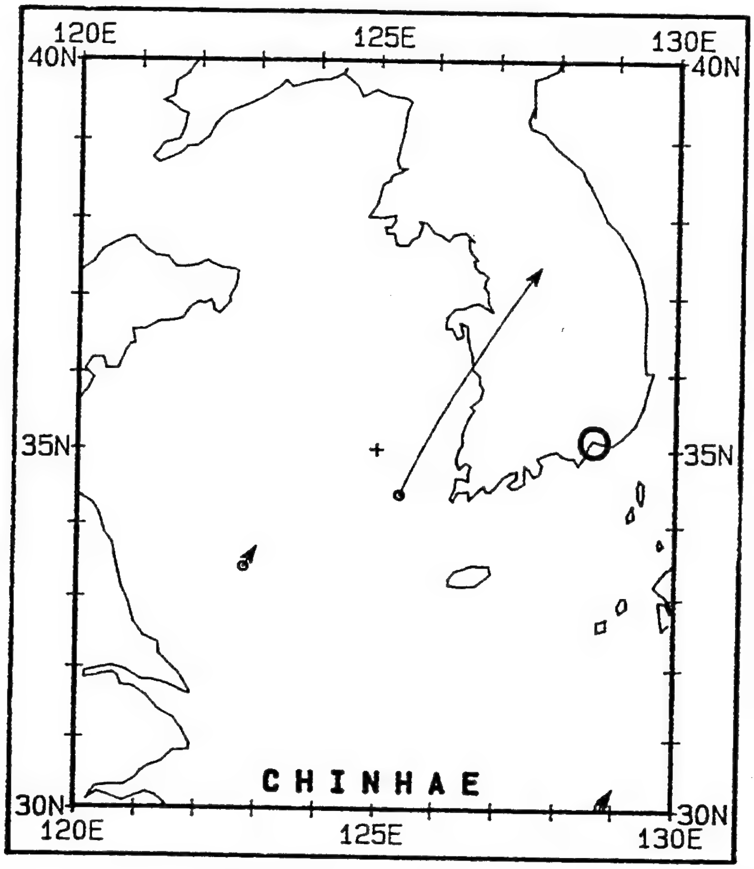


Figure VII-35. Track segments of the tropical storms or typhoons causing sustained winds of at least 22 kt at Chinhae during the period 1951-1954.

A figure showing track segments of tropical cyclone centers when sustained winds of ≥34 kt were observed at Chinhae is not included in this report. Although one storm (Karen in 1952) in Table VII-11 is listed as causing southeast winds of 36 kt with gusts to 52 kt at Chinhae, the duration of winds ≥34 kt lasted less than 30 minutes. A meaningful track segment could not be constructed for that brief period. At the time of the strongest winds, the storm was located approximately 259°/157 nmi from Chinhae.

4.5.5 Waves

The maximum wave heights that can be expected with typhoon strength waves (≥64 kt) in Chinhae Harbor are given in Table VII-12, extracted from a prior evaluation of the Port of Chinhae.

Table VII-12. Maximum wave heights that can be expected with typhoon strength winds (≥64 kt) in Chinhae Harbor.

Location	Northern Part of Harbor	Southern Part of Harbor
Winds generally from the north (tropical cyclone passage east of Chinhae)	3 ft	4 ft
Winds generally from the south (tropical cyclone passage west of Chinhae)	10 ft	8 ft

As Table VII-12 shows, the lack of fetch north of the harbor severely restricts wave generation with northerly winds. The table also shows that southerly winds can result in significantly higher waves in the harbor area. Local harbor personnel state that the maximum wave height at Pier 9 is about 8 ft with strong southerly winds, which is the maximum wave height observed anywhere inside the breakwater.

The wave heights presented in Table VII-12 are intended as a guide only. Specific storms may generate waves that vary from those listed in the table.

4.5.6 Storm Surge and Tides

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the

right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

Although a storm surge is possible, Chinhae is considered to be at minimum risk. A previous typhoon haven evaluation of Chinhae states that a surge effect is evident in the inner harbor during periods of moderate to strong southeasterly winds (tropical cyclone passage west of Chinhae), but during the 1993 port visit, local port authorities stated that there is no known record of storm surge events at the port.

4.6 THE DECISION TO EVADE OR REMAIN IN PORT

4.6.1 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the NPMOCW/JTWC Guam Tropical Cyclone Warnings, and a basic understanding of weather will enable the commander to act in the best interest of the unit, and complete the mission when the unfavorable weather subsides.

Figures VII-33 AND VII-34, discussed earlier, address the probability of existing tropical cyclones later affecting Chinhae. As a further aid for the commander to evaluate a given situation, Figures VII-36 and VII-37 have been prepared. In contrast to Figures VII-33 and VII-34, Figures VII-36 and VII-37 consider only those storms which later passed within 180 nmi of Chinhae. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered as an <u>average</u> approach scenario insofar as Chinhae is concerned. It must be stressed that the other 50% of the storms which later affect Chinhae will be <u>outside</u> of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures VII-36 and VII-37.

CHINHAE

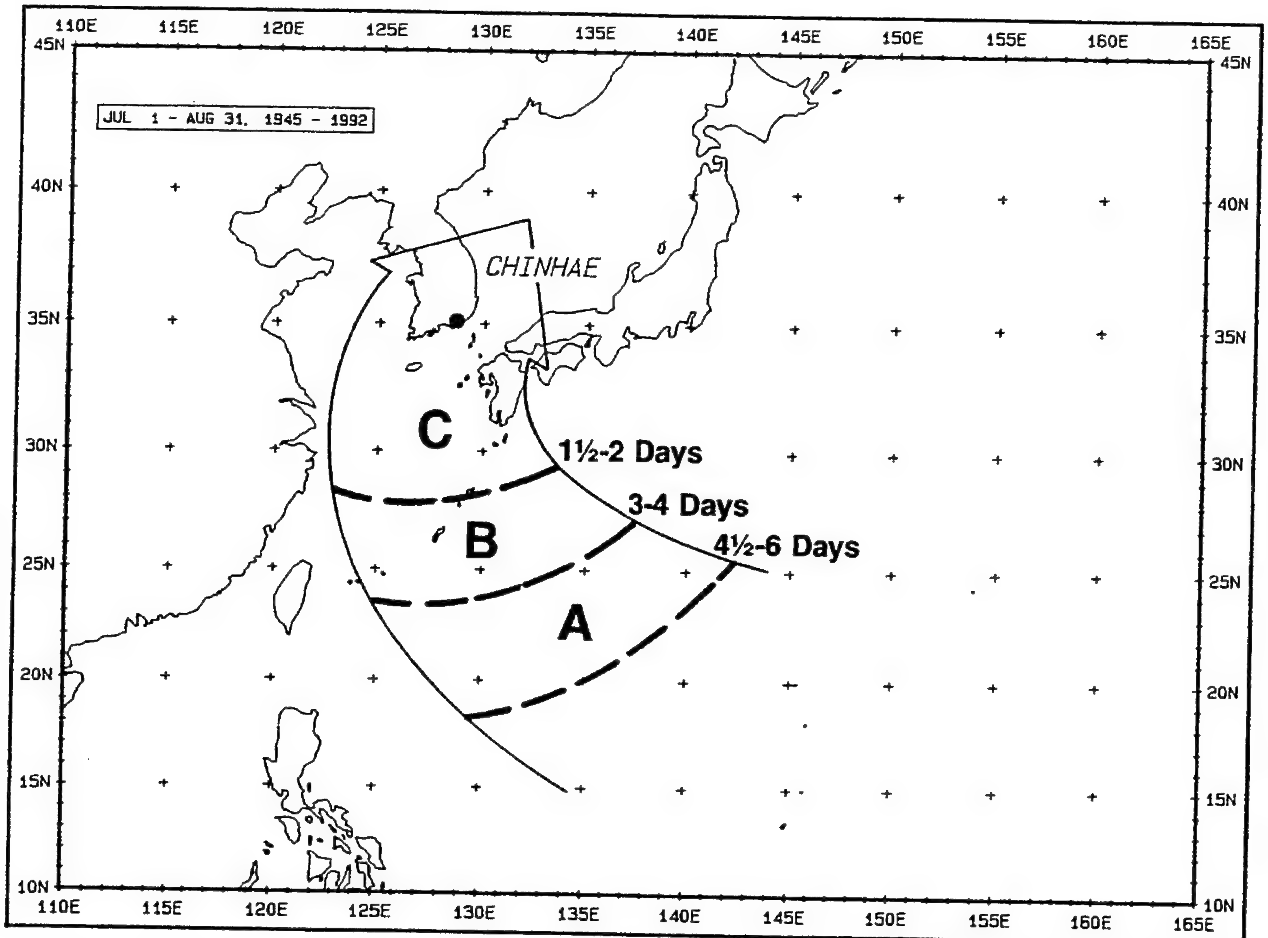
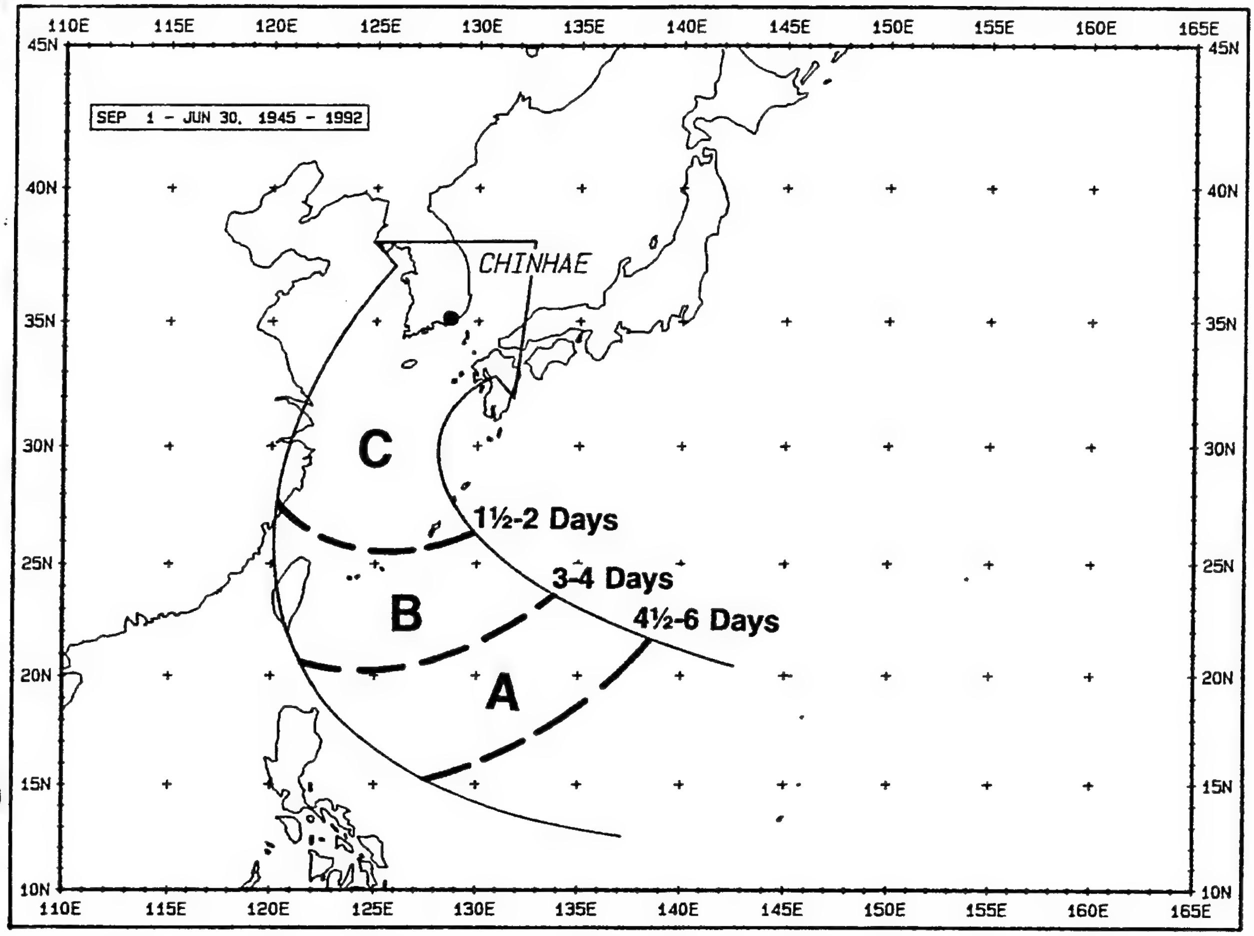


Figure VII-36. Tropical cyclone threat axis for Chinhae for July and August. The area within the limits of the arrow approximates a 50% or greater probability of a tropical cyclone coming within 180 nmi of Chinhae.



Figures VII-37. Tropical cyclone threat axis for Chinhae for the period September through June. The area within the limits of the arrow approximates a 50% or greater probability of a tropical cyclone coming within 180 nmi of Chinhae.

The following time/action sequence, to be used in conjunction with Figures VII-36 and VII-37, has been prepared to aid the commander in planning ship operations.

I. An existing tropical cyclone moves into or development takes place in area A with forecast movement toward Korea:

a. Review material condition of ship. A sortie may be necessary in 48 hours.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters area B with forecast movement toward Chinhae. All concerned should remember that tropical cyclones tend to accelerate rapidly after recurvature:

a. Operational plans should be made. In general:

(1) If winds of less than 80 kt are forecast for the harbor, ships of DD size or smaller may remain in port while larger vessels should move to Chinhae Bay, except that any vessel approaching an AEGIS cruiser in size should sortie from the port. Buoys 5 or 8 are considered to be the safest locations for small ships.

(2) If winds of 80 to 110 kt are forecast for the harbor, all vessels in the harbor should move to Chinhae Bay.

(3) If the wind in the harbor is forecast to exceed 110 kt, all vessels should sortie and evade at sea.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone enters area C moving toward Chinhae:

a. Execute evasion plans made in previous steps.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

4.6.2 Remaining in Port

Due to their large sail area, any vessel approaching an AEGIS cruiser in size should sortie from the port in a typhoon situation.

The berth at Somo Do is vulnerable to south or southeastery winds. As soon as a forecast of strong winds is received, vessels moored at Somo Do should move to anchor in Chinhae Harbor knowing that a subsequent move in accordance with the guidelines listed in 4.6.1 above may be required. During the 1993 port visit, local port authorities stated it may be possible for U. S. Navy submarines to use the new ROK Submarine piers under certain, unspecified conditions.

Although not recommended, properly moored vessels may be allowed to remain alongside at Pier 9 if forecast sustained winds do not exceed gale strength (≥34 kt). Bollards and chocks are in good shape.

For those vessels remaining at Pier 9 and/or incapable of getting underway due to mechanical problems, the following precautions are recommended.

(1) All items capable of becoming flying projectiles in a strong wind should be removed or otherwise secured.

(2) Extra attention should be given to the mooring lines and to the brow during the passage of the storm. Crews should have extra line and wire available and be ready to tend lines during the storm's passage. Local authorities state that no extra wire is available from the port for spring lines, but braided nylon is available.

It should be noted that the harbor is used only by military vessels during strong wind situations. Fishing boats are not permitted.

4.6.3 Evasion

If evasion at sea is desired, steaming into the Yellow Sea or the Sea of Japan are the open ocean sortie options available. The choice will depend on the strength and forecast track of the approaching storm and how early in the planning process the sortie decision is made.

If evasion to the Sea of Japan is selected, the commander must be aware that the ship may be placed in the stronger, and therefore more dangerous, semicircle (the right side of the storm with respect to the storm's direction of movement). The following factors should also be considered:

(1) Lead time. Since tropical cyclones tend to increase their speed of movement after recurvature, planners must provide for an early departure in order to clear the area before the storm's circulation arrives. A storm movement in excess of 30 kt is not uncommon while the storm is still in the vicinity of the Tsushima (Korea) Strait, and may further accelerate when the storm reaches the Sea of Japan. The potentially rapid speed of the tropical cyclone may allow it to overtake evading ships unless the sortie is carefully planned and initiated early in the decision process.

(2) Other potential havens. If the evading unit(s) do not wish to sortie across the Sea of Japan, or if

it appears that the storm may overtake the evading unit(s), commanders may wish to consider using the port of Maizuru, Japan as a typhoon haven. Maizuru (35°29'N 135°23'E) is evaluated in Section V.9 of this manual.

Whichever option is chosen, ship captains should remember that tropical cyclones are historically unpredictable, especially in the recurvature phase. The 48-hour forecast position error may exceed 200 nmi. Consequently, the storm may be closer to or farther from Chinhae than the forecast indicates, or be right or left of its forecast track.

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with LCDR T. Knowles, USN, QMC M. T. Miller, USN and Mr. Hae-il Cho, of Port Operations, Commander Fleet Activities, Chinhae to obtain much of the information contained in this port evaluation.

REFERENCES

FICPAC, 1990: Port Directory for Chinhae (Ginhae), South Korea, Change 11. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Nestor, W. J. R., 1977: The Environment of South Korea and Adjacent Sea Areas. NAVENVPREDRSCHFAC Technical Report No. 77-03. Published by Naval Research Laboratory (formerly Naval Environmental Prediction Research Facility), Monterey, CA 93943.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY

5. **POHANG**

SUMMARY

The conclusion reached in this study is that Pohang is not a typhoon haven. All ships at the port should sortie in a tropical cyclone threat situation. The primary reason for this conclusion is that the port affords no protection from most hazardous tropical cyclone conditions. Any storm passing within 180 nmi of Pohang has the potential to bring strong winds to the port. High seas at the port are possible for all tropical storms moving northeastward through the Tsushima (Korea) Strait or across southwestern Japan into the Sea of Japan.

Evasion from Pohang is recommended in all tropical cyclone threat scenarios. Three viable sortie options exist: evading in the Sea of Japan, evading in the Yellow Sea, or moving to anchor in Chinhae Bay. The option selected will depend on the lead time available to the evading units, and the strength, direction and speed of movement of the approaching tropical cyclone.

5.1 LOCATION

The Port of Pohang is located on the east coast of the Korean Peninsula in the southwestern part of the Sea of Japan at 36°01'N 129°25E (Figures VII-1 and VII-1A).

5.2 POHANG HARBOR

Pohang has two harbors, a natural harbor and a new, man-made harbor. Approach is made from the northeast through Yeongil Bay (Figure VII-38). The natural harbor (36°02'N 129°22'E) is not suitable for use by large ocean-going vessels and is used primarily by Pohang's commercial fishing fleet (FICPAC, 1993).

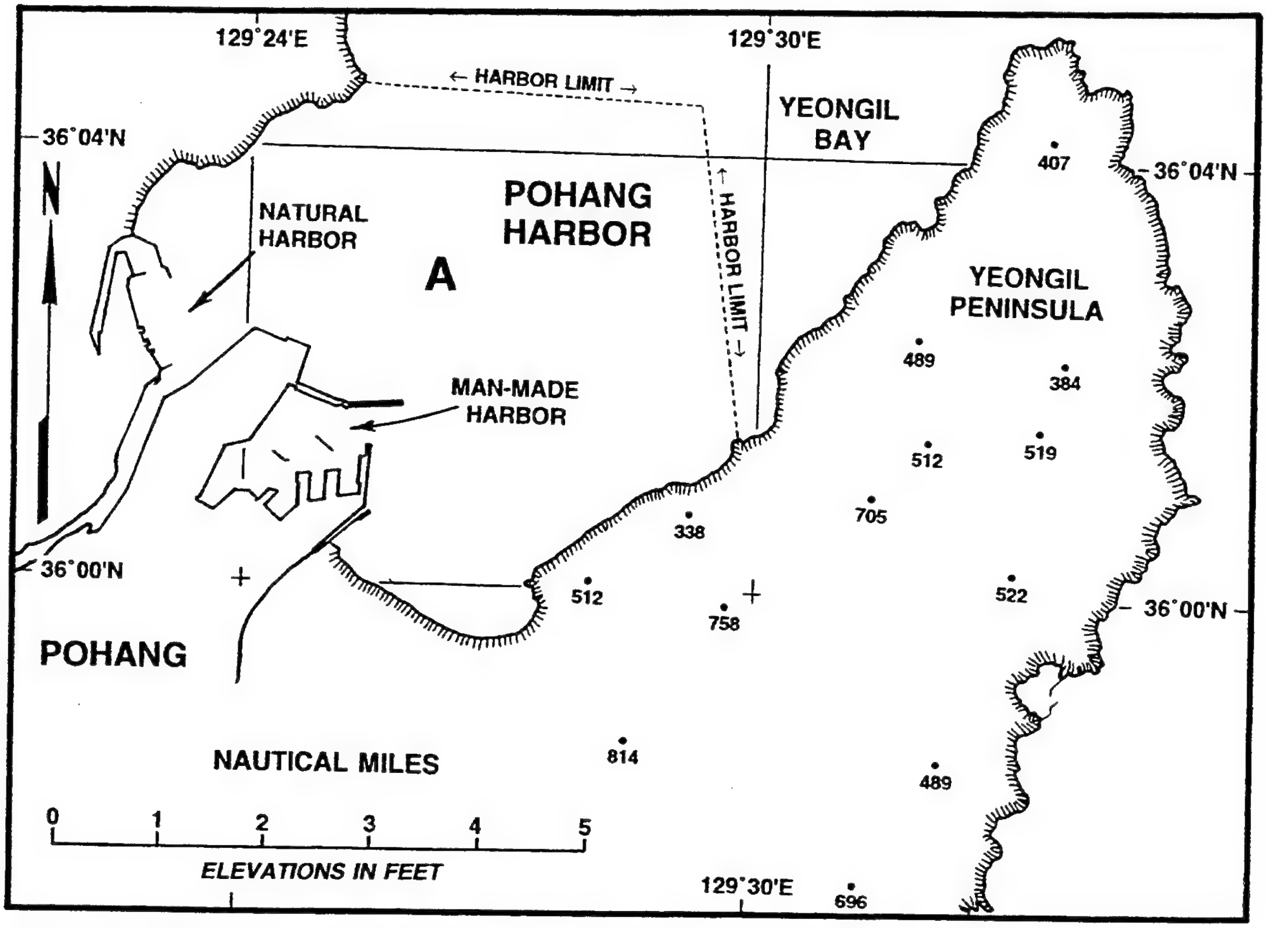


Figure VII-38. Pohang Harbor and its location in relation to Yeongil Bay and Yeongil Peninsula.

The much larger, man-made harbor is located about 1.5 nmi southeast of the natural harbor and serves as the primary import and export facility for Pohang Iron and Steel Company (POSCO) (Figure VII-39). It is the harbor of primary interest to this evaluation.

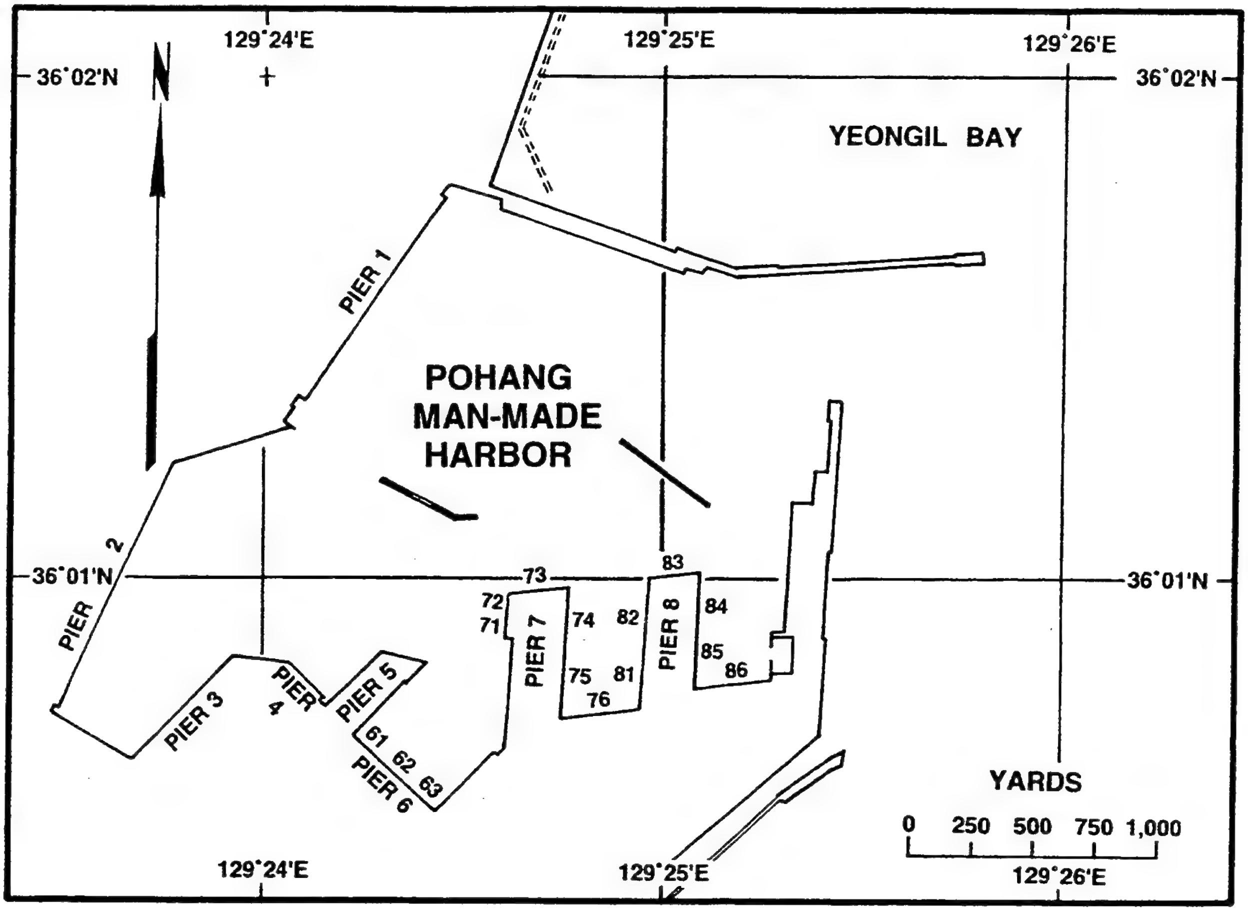


Figure VII-39. Pohang Harbor.

The north side of the harbor is protected by a combined breakwater and loading/unloading wharf. The wharf, approximately 2,025 yd (1,882 m) long, extends east-southeastward from the reclaimed area that forms the northwest part of the harbor. The eastern half of the structure is a breakwater only; the western half serves the dual-purpose of acting as a protective breakwater and as a railroad accessible loading/unloading wharf. The east side of the harbor is defined by an approximately 1,350 yd (1,235 m) long combined wharf facility and breakwater.

The entrance to the inner harbor is situated between the two protective breakwaters in the northeast corner of the man-made

inner harbor. It has a usable width of 328 yd (300 m) with a depth of 59 ft (18 m) near the center of the channel.

Two detached breakwaters are located in the inner harbor (Figure VII-39). The easternmost is approximately 450 yd (411 m) long and the westernmost is approximately 400 yd (366 m) long. The two breakwaters provide increased protection from waves for the facilities in the southwestern part of the inner harbor.

Pilotage is compulsory at Pohang for ships entering and leaving the port.

According to DMA Chart 95163, tides are minimal at Pohang with a spring rise of only about 8 inches (0.2 m). Currents at the port entrance are generally weak and do not pose a problem to ships entering or leaving Pohang Harbor.

5.3 HARBOR FACILITIES

The man-made harbor at Pohang has eight piers. Piers 1 through 5 are used for coal, iron ore, and scrap steel in support of the POSCO steel complex. Piers 6, 7 and 8 are general cargo piers. The numbered locations of the general cargo berths are shown on Figure VII-39. When U. S. Navy ships visit the inner harbor at Pohang, it is usually in support of amphibious training operations conducted jointly with Republic of Korea armed forces. U. S. Navy ships are normally assigned to Pier 8, and have used berths 76, 81, 82, 83, 84, 85 and 86 during past visits. According to port authorities and DMA Chart 95167, depths adjacent to Pier 8 are approximately 36 ft (11 m), but a 1993 visit by a U. S. Navy ship reported 66 ft (20 m) alongside berth 85. The port can accommodate ten amphibious ships, including an LPH and an LHA (FICPAC, 1993). Table VII-13, adapted from a

locally produced port document, lists the berth specifications for the general cargo berths.

Table VII-13. Berth specifications of general cargo berths.

PIER	BERTH NO.	LENGTH (FT)	DEPTH (FT)	CAPACITY
6	1,2,3	1,230	17.4	2,000DWT x 3V
7	1,2,3,4,5,6	4,390	39.4	10,000DWT x 2V
				30,000DWT x 2V
				20,000DWT x 2V
8	1,2,3,4,5,6	4,750	36.1	30,000DWT x 2V
				10,000DWT x 2V
				20,000DWT x 2V

Other facilities used by U. S. Navy ships include the primary anchorage north and northeast of the inner harbor, and the beach southeast of the port entrance. The anchorage is said to offer good holding on a mud and sand bottom in depths mostly in the 49 to 82 ft (15 to 25 m) range. The approximate center position of the anchorage is indicated by the letter "A" on Figure VII-38. There are 18 identified anchorage positions at Pohang, with 15 located in the primary anchorage and 3 located southeast of the harbor in somewhat shallower depths. The anchorage, exposed to winds and waves, could make anchoring inadvisable because of the danger of potential anchor dragging and curtailment of small boat operations. Instead of anchoring, amphibious ships occasionally will make slow turns around the anchorage while off-loading cargo into landing craft for transport to the beach south of the port.

According to local port authorities, seven tug boats are available at the port. When an LHA visited the port in 1993, four tugs (three of 3,000 hp and one of 2,600 hp) were used to

turn the ship 80° onto berth 85 (FICPAC, 1993). The port has only limited ship repair facilities, with services confined to emergency hull repairs and welding.

5.4 TOPOGRAPHY

The harbor is open and exposed to the northeast through Yeongil Bay (Figure VII-38). Yeongil Bay is formed on the east by the Yeongil Peninsula which extends about 8 nmi north-northeast from the Korean mainland. The topography of the peninsula is rugged, with elevations commonly exceeding 460 ft (140 m). One peak reaches 814 ft (248 m) within 4 nmi of the harbor entrance.

The terrain west of the port is similarly rugged, with extensive areas of sharp rises dominating the countryside. The Taehwa Rift Valley, identified in The Environment of South Korea and Adjacent Sea Areas, extends southwest from Pohang on the east side of the Taebaek Mountain range. The general topography of the area adjacent to Pohang and the approximate location of the Taehwa Rift Valley are shown on Figure VII-40.

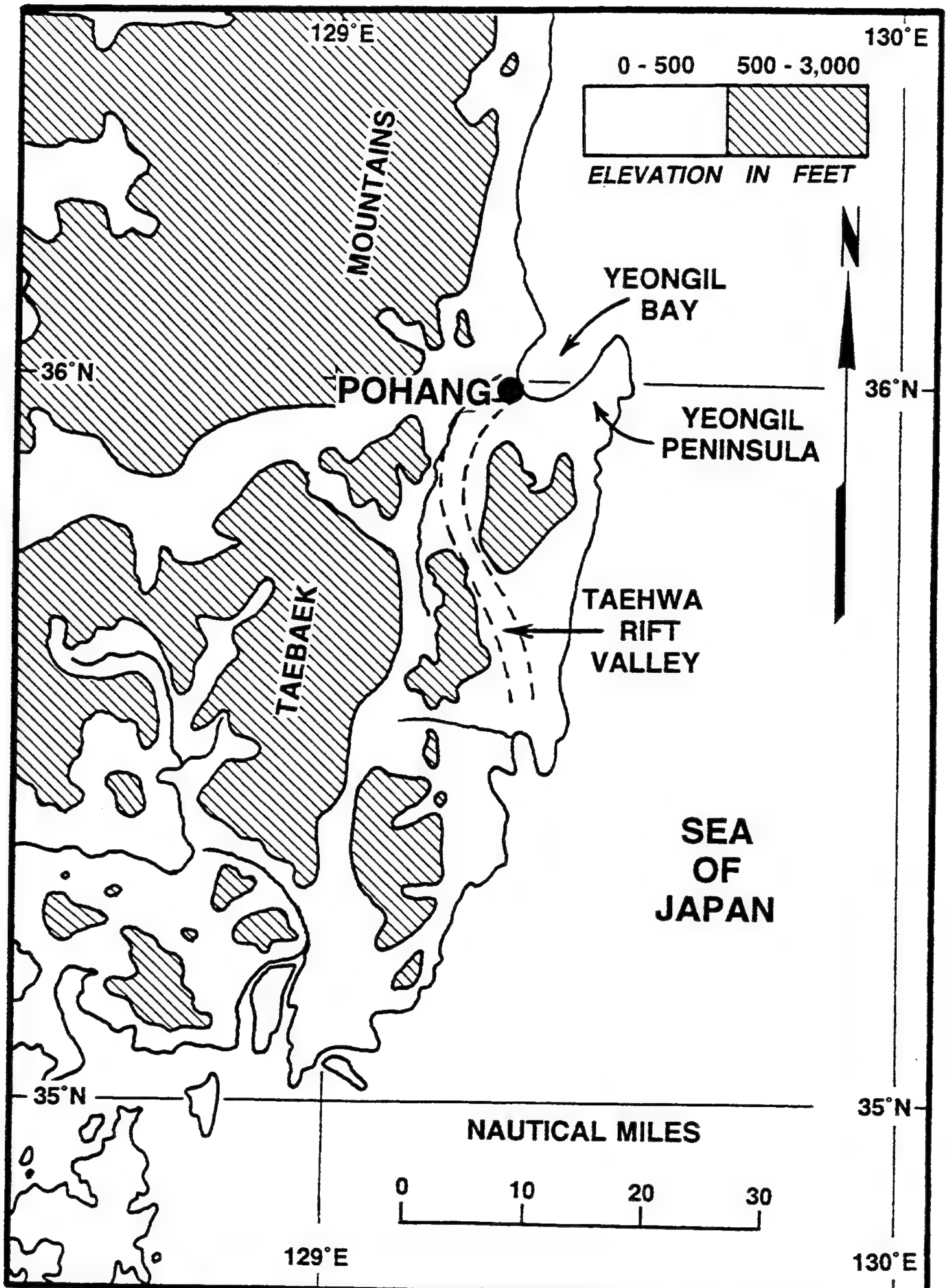


Figure VII-40. Topography of Korea adjacent to Pohang.

5.5 TROPICAL CYCLONES AFFECTING POHANG

5.5.1 Tropical Cyclone Climatology at Pohang

For the purpose of this study, any tropical storm or typhoon approaching within 180 nmi of Pohang is considered to represent a threat to the port. Table VII-14 contains a descriptive history of all tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992. All of the tropical cyclone statistics used in this report for storms passing within 180 nmi of Pohang are based on the data set used to compile Table VII-14.

Tropical cyclones which affect Korea generally have the same genesis area as those affecting Japan, 5°N to 30°N and 120°E to 165°E. The latitudinal boundaries shift poleward during the summer months and then equatorward in winter in response to the seasonal changes of the synoptic environment. Most of the storms affecting Pohang move northwestward from the genesis area to the East China Sea or western Philippine Sea south of the island of Kyushu, Japan before recurving north or northeastward to within 180 nmi of Pohang.

Table VII-14. Descriptive history of all tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
1	EVA	1945	AUG	4	9	40	117 (W)	360/26.0
2	RUTH	1945	AUG	26	13	40	161 (ENE)	348/11.3
3	URSULA	1945	SEP	13	17	42	62 (NW)	062/23.2
4	LILLY	1946	AUG	20	8	43	91 (SW)	323/ 8.5
5	PEARL	1948	JUL	7	6	50	179 (NW)	027/16.3
6	DELLA	1949	JUN	21	2	50	83 (E)	359/11.0
7	FAYE	1949	JUL	18	4	40	70 (ESE)	025/ 7.7
8	JUDITH	1949	AUG	18	8	25	79 (SSE)	051/ 3.2
9	ELSIE	1950	JUN	24	3	52	67 (ESE)	037/37.8
10	GRACE	1950	JUL	21	5	30	117 (W)	360/ 3.1
11	KEZIA	1950	SEP	13	9	50	93 (ESE)	014/23.7
12	MARGE	1951	AUG	23	7	46	130 (WNW)	017/21.5
13	KAREN	1952	AUG	18	8	53	115 (NW)	036/19.4
14	MARY	1952	SEP	3	10	45	131 (NW)	042/36.4
15	KATHY	1954	SEP	7	9	50	129 (ESE)	020/26.2
16	JUNE	1954	SEP	13	10	55*	120 (ENE)	338/23.5
17	LOUISE	1955	SEP	30	15	83	111 (ESE)	016/26.3
18	MARGE	1955	OCT	3	16	51	170 (ESE)	028/20.8
19	BABS	1956	AUG	17	9	80	117 (SE)	048/21.0
20	EMMA	1956	SEP	9	12	102	42 (ESE)	030/28.5
21	VIRGINIA	1957	JUN	27	5	48	145 (SSE)	073/34.0
22	AGNES	1957	AUG	21	7	45	61 (W)	006/25.1
23	SARAH	1959	SEP	17	14	96	8 (SSE)	039/23.9
24	CARMEN	1960	AUG	23	14	45	163 (WNW)	023/37.4
25	BETTY	1961	MAY	28	6	35	42 (SSW)	061/32.7
26	HELEN	1961	AUG	2	12	35	92 (WSW)	339/ 9.6
27	JOAN	1962	JUL	10	5	40	122 (WNW)	035/26.1
28	NORA	1962	AUG	2	8	38	163 (NW)	055/36.5
29	AMY	1962	SEP	7	17	33	147 (NNW)	063/35.3
30	SHIRLEY	1963	JUN	20	4	50	25 (WNW)	043/29.8
31	BESS	1963	AUG	10	9	34	68 (ESE)	023/ 9.1
32	KATHY	1964	AUG	24	15	60	174 (SE)	042/13.7
33	DINAH	1965	JUN	20	10	32	160 (ESE)	032/23.6
34	JEAN	1965	AUG	6	16	78	135 (ESE)	033/23.4
35	BETTY	1966	AUG	30	16	30	93 (W)	053/ 8.1
36	POLLY	1968	AUG	16	7	40	50 (SE)	046/28.0
37	DELLA	1968	SEP	25	15	35	170 (SSE)	024/12.9
38	WILDA	1970	AUG	14	8	65	133 (SE)	039/21.5
39	ANITA	1970	AUG	21	9	73	151 (E)	015/19.2
40	OLIVE	1971	AUG	5	19	54	61 (E)	005/19.0
41	TESS	1972	JUL	23	10	43	73 (ESE)	011/20.9
42	IRIS	1973	AUG	17	10	37	171 (WNW)	018/21.0
43	GILDA	1974	JUL	6	9	43	25 (SE)	031/18.7
44	POLLY	1974	SEP	1	18	49	144 (E)	355/16.9
45	PHYLLIS	1975	AUG	17	7	37	49 (E)	360/ 7.0
46	FRAN	1976	SEP	13	17	45	108 (ESE)	030/22.0
47	WENDY	1978	AUG	2	8	40	161 (SSE)	024/16.9
48	IRMA	1978	SEP	15	18	40	142 (SSE)	065/19.2
49	IRVING	1979	AUG	17	12	34	64 (NW)	049/23.2
50	ORCHID	1980	SEP	11	17	48	127 (E)	012/30.7
51	ELLIS	1982	AUG	27	14	44	126 (E)	358/28.0
52	KEN	1982	SEP	25	20	45	154 (E)	357/22.0
53	HOLLY	1984	AUG	21	11	56	61 (SE)	048/17.0
54	KIT	1985	AUG	10	8	40*	53 (NW)	040/22.5
55	ODESSA	1985	AUG	31	12	43	96 (SE)	044/18.0
56	PAT	1985	AUG	31	13	75	75 (ESE)	022/24.6
57	BRENDA	1985	OCT	5	20	65	150 (SSW)	042/25.9
58	NANCY	1986	JUN	25	5	40	74 (SE)	050/30.1
59	VERA	1986	AUG	28	14	48	115 (NW)	036/20.0
60	THELMA	1987	JUL	15	5	58*	71 (WNW)	020/25.2

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 36.0°N, 129.4°E.

Table VII-14 (continued). Descriptive history of all tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992. Winds and forward speeds are in knots.

1 STORM INDEX NUMBER	2 STORM NAME	3 YEAR	4 MONTH	5 DAY	6 STORM NUMBER FOR YEAR	7 MAXIMUM WIND AT STORM CENTER	8 CPA (CLOSEST POINT OF APPROACH)	9 DDD/SS.S DDD=HEADING SS.S=FORWARD SPEED AT CPA
61	DINAH	1987	AUG	30	11	68	38 (ESE)	032/33.2
62	ELLIS	1989	JUN	24	6	35	120 (ESE)	029/23.3
63	JUDY	1989	JUL	28	11	42	103 (W)	001/18.7
64	ZOLA	1990	AUG	22	14	83	165 (E)	013/28.4
65	CAITLIN	1991	JUL	29	9	67	51 (ESE)	037/18.8
66	GLADYS	1991	AUG	23	14	40	128 (SW)	306/ 8.9
67	KINNA	1991	SEP	14	19	73	143 (SE)	044/32.0
68	MIREILLE	1991	SEP	27	21	88	134 (SE)	044/38.5
69	IRVING	1992	AUG	5	10	25	77 (SSW)	025/ 7.7
70	JANIS	1992	AUG	8	11	68	161 (SE)	041/19.4
71	KENT	1992	AUG	19	12	28	80 (ESE)	012/12.3
72	TED	1992	SEP	24	20	37	12 (NNW)	074/29.4

NOTES:
Datetimes are in UTC, winds are in knots, distances are in nautical miles. Parenthetical expression in column 8 gives bearing of storm from site at closest point of approach to site (CPA). Maximum winds are at time of CPA and did not necessarily occur at site. Asterisk (if any) after maximum wind indicates that storm was classified as a typhoon (at least 64 kts) somewhere within 180 nautical mile radius of site but not at CPA. Site location is 36.0°N, 129.4°E.

An examination of Table VII-15 shows that June through September is the primary season for tropical cyclone activity at Pohang, with 96% (69 of 72) occurring during that four-month period. August is the month of greatest threat, with 49% (35 of 72) of the tropical cyclones occurring during the month. One storm was recorded in late May (on the 28th of the month) and two have occurred during early October (on the 3rd and 5th). The average movement of all 72 storms at closest point of approach (CPA) to Pohang was 025° 22 kt.

Table VII-15. Frequency and motion of tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992.

Total number of storms passing within 180 n mi	0	0	0	0	1	7	9	35	18	2	0	0	72
Number of storms having at least typhoon intensity at CPA	0	0	0	0	0	0	1	8	5	1	0	0	15
Number of storms less than typhoon intensity at CPA	0	0	0	0	1	7	8	27	13	1	0	0	57
Average heading (degs) towards which storms were moving at CPA	---	---	---	---	*	037	021	020	030	*	---	---	025
Average storm speed (knots) at CPA	---	---	---	---	*	27	18	19	26	*	---	---	22
Month when storm was at CPA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR

** indicates insufficient storms for average direction and speed computations.*

During the 48-year period from 1945 through 1992 there were 72 tropical storms and typhoons that met the 180 nmi threat criterion for Pohang, an average of 1.5 per year. Figure VII-41 depicts the monthly distribution of the 72 storms by 7-day periods. The figure shows that, while the period of most tropical cyclone activity extends from June through the first week of October, typhoon strength storms (at CPA) have not been recorded within 180 nmi of Pohang until late July.

POHANG

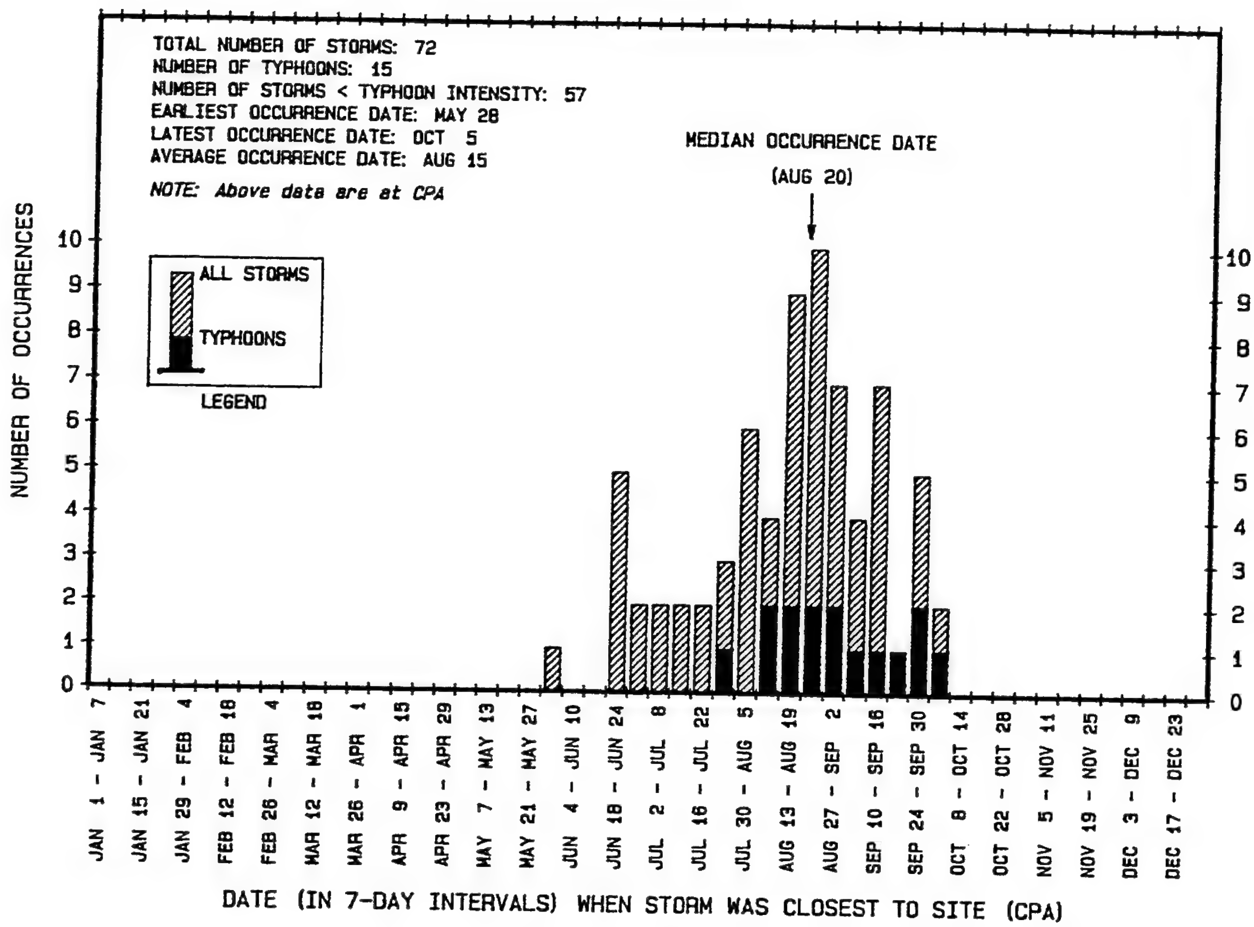


Figure VII-41. Monthly distribution of the 72 tropical storms or typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992.

Figure VII-42 depicts the annual distribution of tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945 through 1992. The annual frequency ranges from 0 to 4.

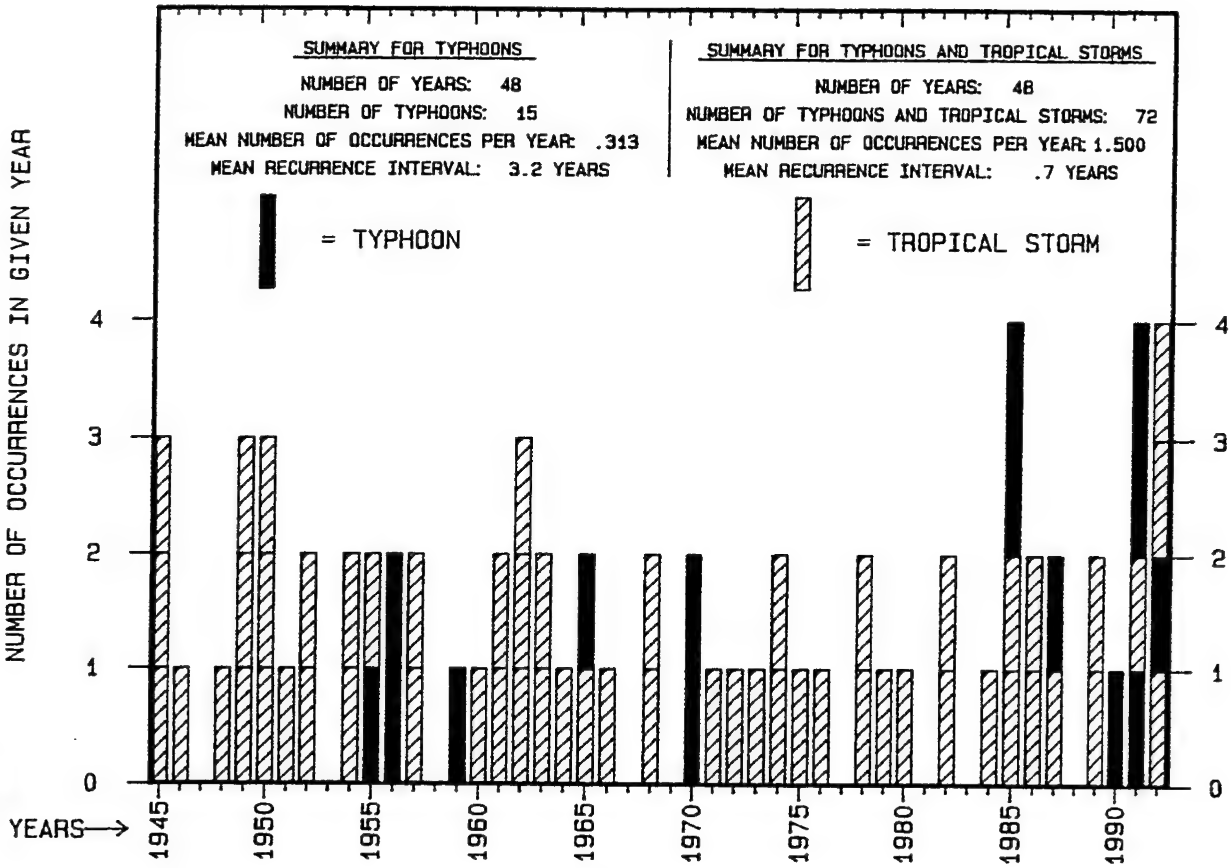


Figure VII-42. Chronology of the 72 tropical storms and typhoons passing within 180 nmi of Pohang during the 48-year period 1945-1992.

Figure VII-43 depicts, on an 8-point compass, the octants from which the 72 tropical cyclones in the data set approached Pohang. Over 94% (68 of 72) of the storms approached Pohang from either southwest (60%) or south (35%) octants. These predominant approach directions are largely due to Pohang's position relative to the primary tropical cyclone storm track discussed above. Most of the storms have recurved or are in the process of recurving when they are at CPA to Pohang.

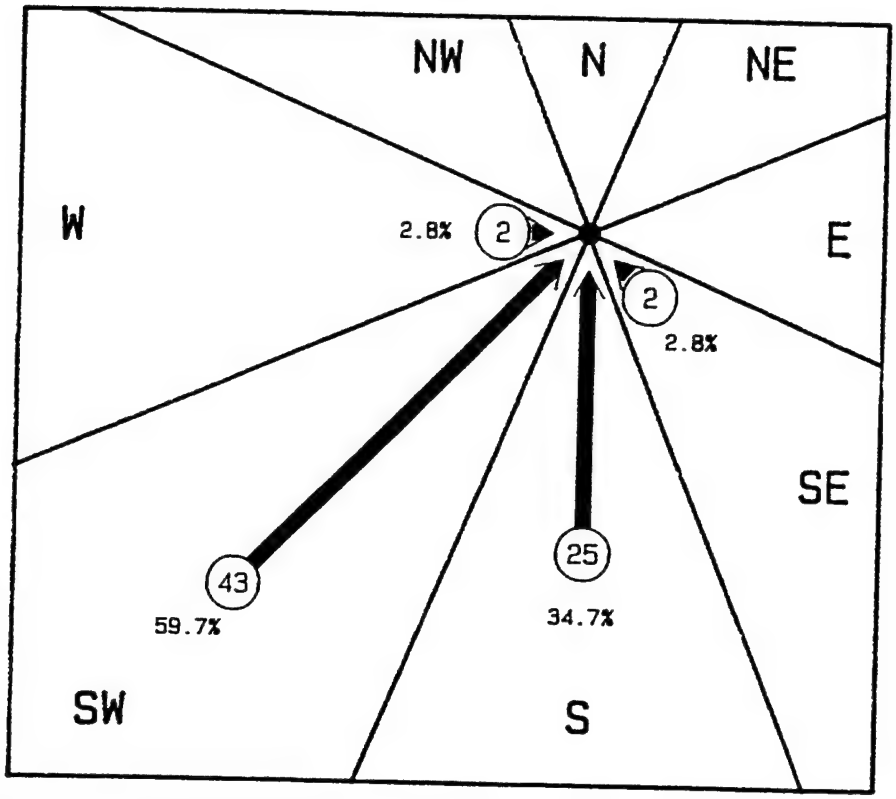


Figure VII-43. Directions of approach for the 72 tropical cyclones passing within 180 nmi of Pohang during the 48-year period of record.

Figures VII-44 and VII-45 provide information on the probability of remote tropical storms and/or typhoons passing within 180 nmi of Pohang and average time to CPA. The thin, solid lines represent a "percent threat" for any tropical cyclone location within the area depicted. The heavy, dashed lines represent the approximate time in days for a system to reach Pohang. For example, in Figure VII-44, during the months of July and August a tropical cyclone located at 25°N 135°E has an approximate 25% probability of passing within 180 nmi of Pohang, and will reach Pohang in about 3 to 4 days.

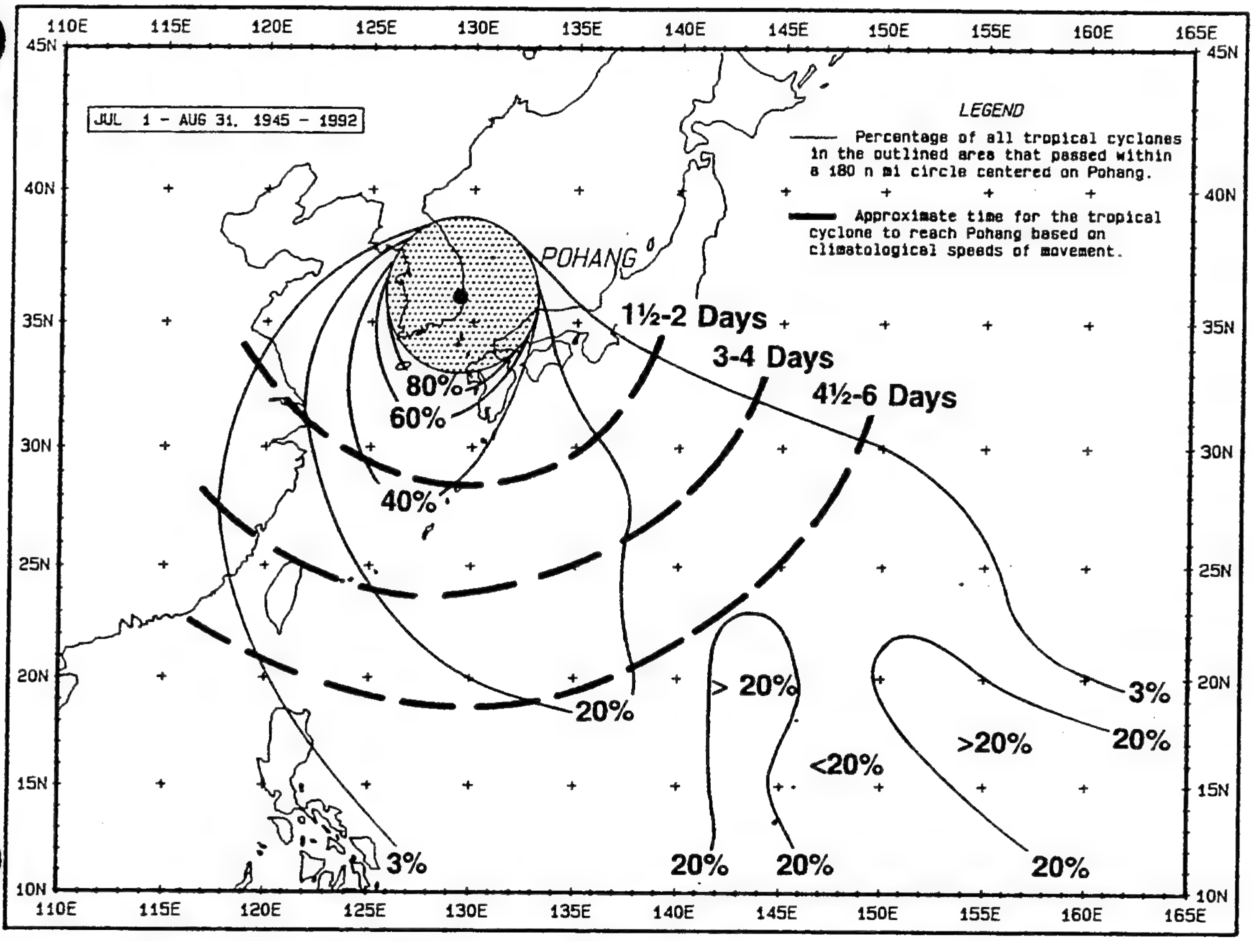


Figure VII-44. Probability that a tropical storm or typhoon will pass within 180 nmi of Pohang (circle), and approximate time to closest point of approach, during July and August.

A comparison of Figures VII-44 and VII-45 shows that there are distinct differences in threat axes according to the time of year. The July and August storm axis extends south-southwest from Pohang to about 30°N before turning south and then southeastward to more tropical latitudes. The September through June axis extends southwestward from Pohang to the coast of the People's Republic of China before turning southward across Taiwan and, ultimately, southeastward across the Philippine Sea to the lower latitudes.

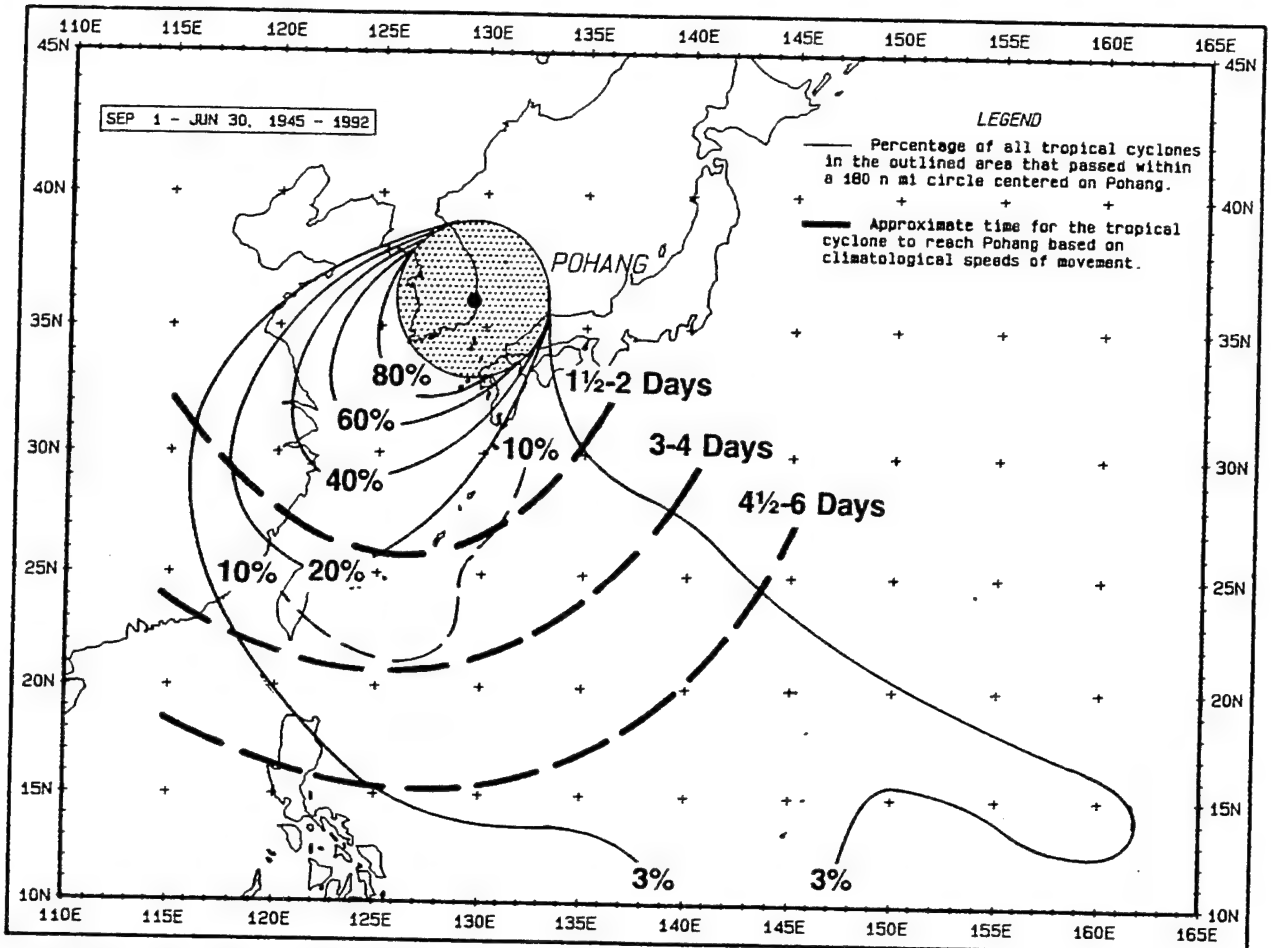


Figure VII-45. Probability that a tropical storm or typhoon will pass within 180 nmi of Pohang (circle), and approximate time to closest point of approach, during the period September through June.

5.5.2 Topographical Effects

The wind observation equipment for the Port of Pohang is located approximately 3 nmi northwest of the harbor on a mast atop a multi-level building about 100 yd from the beach. The elevation of the anemometer is estimated to be 50 to 60 ft above sea level. The site appears to be fairly representative of most wind conditions experienced at the port.

The hills of Yeongil Peninsula (Figure VII-38) provide limited protection from easterly winds, and the Taebaek Mountains

would provide protection from strong west to northwesterly wind flow. The port is exposed and vulnerable to winds from north through northeast, and southeast through southwest. As can be seen in Table VII-16 below, the strongest winds experienced at Pohang are mostly from north through northeast and southeast through south.

5.5.3 Local Weather Conditions

The data contained in Table VII-16 have been extracted from observations recorded at Pohang during the period 1973 through 1992[1]. No observations are available for Pohang prior to 1973.

A total of 72 tropical storms or typhoons passed within 180 nmi of Pohang during the period 1945 through 1992. Of these, 31 occurred when observational data are available--1973 through 1992. Six of the 31 storms caused sustained winds ≥34 kt at Pohang, and 21 (including those that caused winds ≥34 kt) caused winds ≥22 kt.

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[1]Based on observations provided by Fleet Numerical Meteorology and Oceanography Detachment, Asheville, NC.

Table VII-16. Center data and related weather associated with selected tropical cyclone passages within 180 nmi of Pohang 1973-1992.

TROPICAL CYCLONE DATA				RELATED LOCAL WEATHER	
DATE (NAME)	MVMT DIR/SOA (KT)	DIR/CPA FM STAT (NMI)	CNTR WIND (KT)	MAX WIND & GUSTS (KT)	WEATHER AND PRECIP AMT./ ACCUM. PERIOD IF KNOWN
74/07/06 (GILDA)	031/19	128/25	43	N 36G42	HEAVY RAIN 7.24"/24 HRS
76/09/12 (FRAN)	030/22	120/108	45	N 36G49	HEAVY RAIN 1.50"/24 HRS
79/08/17 (IRVING)	049/23	320/64	34	SE 28G42	HEAVY RAIN
80/09/10 (ORCHID)	012/31	095/127	48	N 25	HEAVY RAIN 3.03"/24 HRS
82/09/24 (KEN)	357/22	101/154	45	NNE 28	LIGHT RAIN
85/08/10 (KIT)	040/23	321/53	40	SE 32G49	HEAVY RAIN
85/10/05 (BRENDA)	042/26	208/150	65	NNE 35	RAIN 2.20"/UNKNOWN
86/08/28 (VERA)	036/20	311/115	48	SE 40G58	HEAVY RAIN
87/07/15 (THELMA)	020/25	290/71	58	ESE 50G86	HEAVY RAIN
87/08/30 (DINAH)	032/33	104/38	68	NNE 40G65	HEAVY RAIN
91/07/29 (CAITLIN)	037/19	124/51	67	NE 25	RAIN SHOWERS 1.57"/UNKNOWN
91/08/22 (GLADYS)	306/9	215/128	40	NNE 29	HEAVY RAIN 6.42"/UNKNOWN
91/09/27 (MIRIELLE)	044/39	139/134	88	N 30	RAIN 2.72"/UNKNOWN
92/09/24 (TED)	074/29	346/12	37	S 25	HEAVY RAIN

5.5.4 Wind

The beginning and end points of the arrows in Figure VII-46 give the positions of tropical cyclone centers when sustained winds ≥22 kt began and ended at Pohang for 21 of the 31 tropical cyclones that passed within 180 nmi during the period 1973-1992.

Due to the location of Pohang on the east coast of the rugged terrain of the Korean Peninsula, most of the tropical cyclones causing strong winds at Pohang pass east of the port, either through the Tsushima (or Korea) Strait or over the islands of southwestern Japan. Figure VII-47 shows the positions of the centers of the six tropical cyclones that brought sustained winds ≥34 kt at Pohang for the same period. Each track in Figure VII-47 is identified by an index number that corresponds to the listing in Table VII-14. As can be seen in Figure VII-46, 15 of the 21 storms causing winds ≥22 kt at Pohang passed east of the port. Figure VII-47 shows that 2 of the 6 storms causing winds ≥34 kt passed west of Pohang.

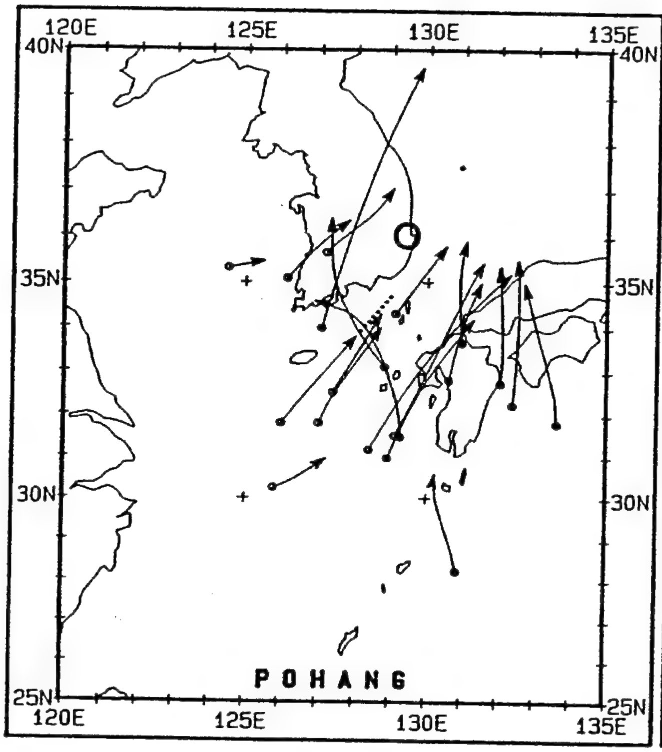

Figure VII-46

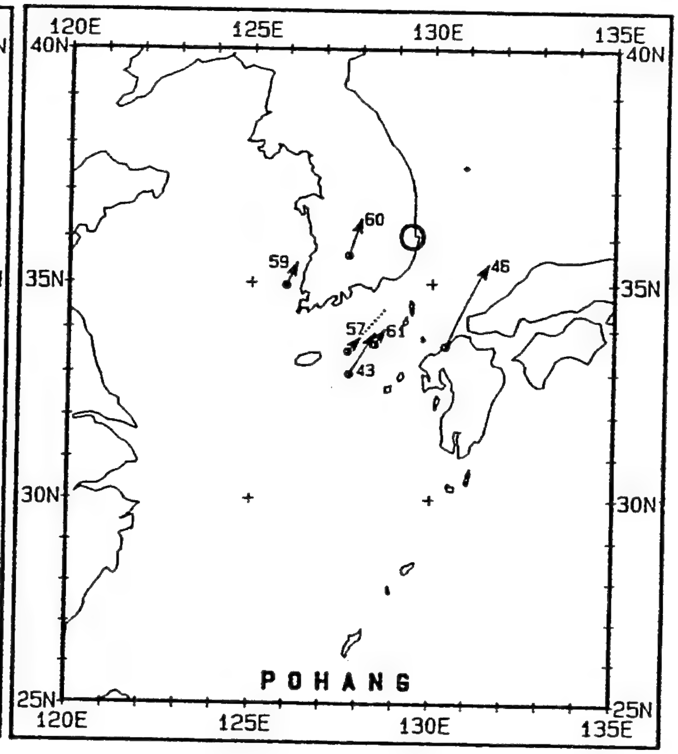

Figure VII-47

Figures VII-46 and VII-47. Track segments of the tropical storms or typhoons causing sustained winds ≥22kt (Figure VII-46) or ≥34 kt (Figure VII-47) at Pohang during the period 1973-1992.

5.5.5 Wave Motion

Ships in the anchorage are exposed to any wave motion from north through northeast. Local port authorities state that waves of 6.5 to 13.2 ft (3 to 4 m) have been noted outside the entrance to the man-made harbor, and waves of 6.5 to 10 ft (2 to 3 m) have been experienced inside the harbor entrance. The landmass of the Korean Peninsula effectively precludes the approach of any significant waves from east clockwise through northwest at Pohang.

5.5.6 Storm Surge and Tides

Storm surge may be visualized as a raised dome of water, moving with the storm, and centered a few miles to the right of its path. The dome height is related to local pressure (i.e., a barometric effect dependent on the intensity of the storm) and to wind stress on the water caused by local winds. Other significant contributing factors are storm speed, direction of approach, bottom topography, and coincidence with astronomical tide.

The worst combination of circumstances (Harris, 1963, and Pore and Barrientos, 1976) would include:

(1) An intense storm approaching perpendicular to the coast with the harbor within 30 nmi to the right of the storm's track.

(2) Broad, shallow, slowly shoaling bathymetry.

(3) Coincidence with high astronomical tide.

The potential vulnerability of Pohang to storm surge is uncertain. Pohang's location relative to the normal track for tropical cyclone movement through the Tsushima (or Korea) Strait or across southwestern Japan would place the port on the weaker, left side (with respect to the storm's direction of movement) of the storm's circulation, and reduce the duration and impact of the wind and its effects. Consequently, the criterion stated in paragraph (1) above would not likely be met. Also, the location of the port on the relatively deep Sea of Japan precludes the broad, shallow, slowly shoaling bathymetry criterion stated in paragraph (2) above.

Local port authorities state that a minimal

storm surge, in the range of 12 to 15 inches (30 to 40 cm), has been noted in the past.

5.6 THE DECISION TO EVADE OR REMAIN IN PORT

5.6.1 Evasion Rationale

It is of utmost importance that the commander recognize the inherent dangers that exist when exposed to the possibility of hazardous weather. Proper utilization of meteorological products, especially the Naval Pacific Meteorology and Oceanography Center West/Joint Typhoon Warning Center (NPMOCW/JTWC) Guam Tropical Cyclone Warnings, and a basic understanding of weather will enable the commander to act in the best interest of his unit, and complete his mission when the unfavorable weather subsides.

Figures VII-44 and VII-45, discussed earlier, address the probability of existing tropical cyclones later affecting Pohang. As a further aid for the commander to evaluate a given situation, Figures VII-48 and VII-49 have been prepared. In contrast to Figures VII-44 and VII-45, Figures VII-48 and VII-49 consider only those storms which later passed within 180 nmi of Pohang. Approximately 50% of these storms are contained within the bounds shown by the arrow. Thus, the arrow and the associated timing arcs can be considered as an average approach scenario insofar as Pohang is concerned. It must be stressed that the other 50% of the storms which later affect Pohang will be outside of these bounds. Another important factor is that the actual JTWC forecast will always take precedence over the tracks and translational storm speeds suggested by Figures VII-48 and VII-49.

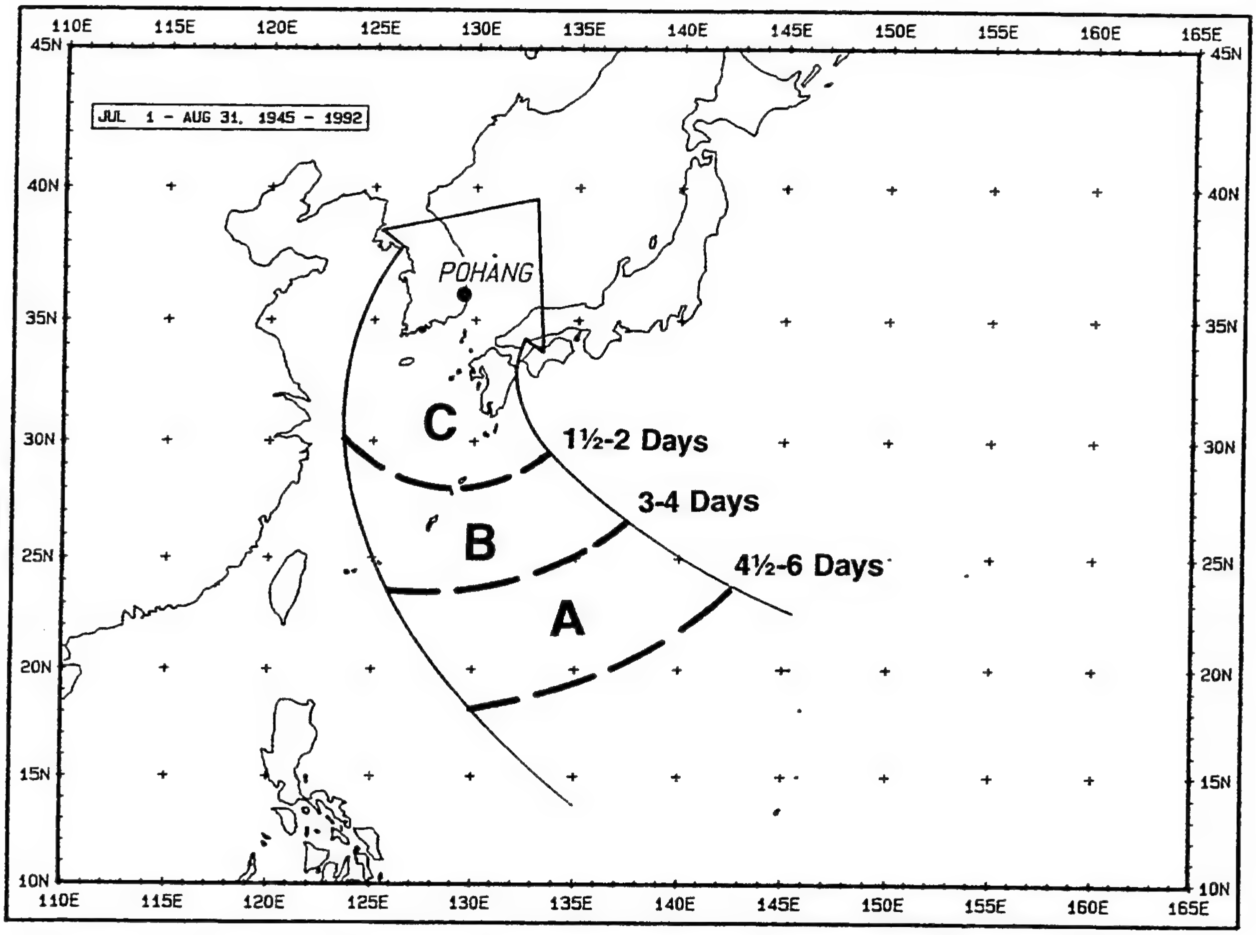

Figure VII-48. Tropical cyclone threat axis for Pohang for July and August.

POHANG

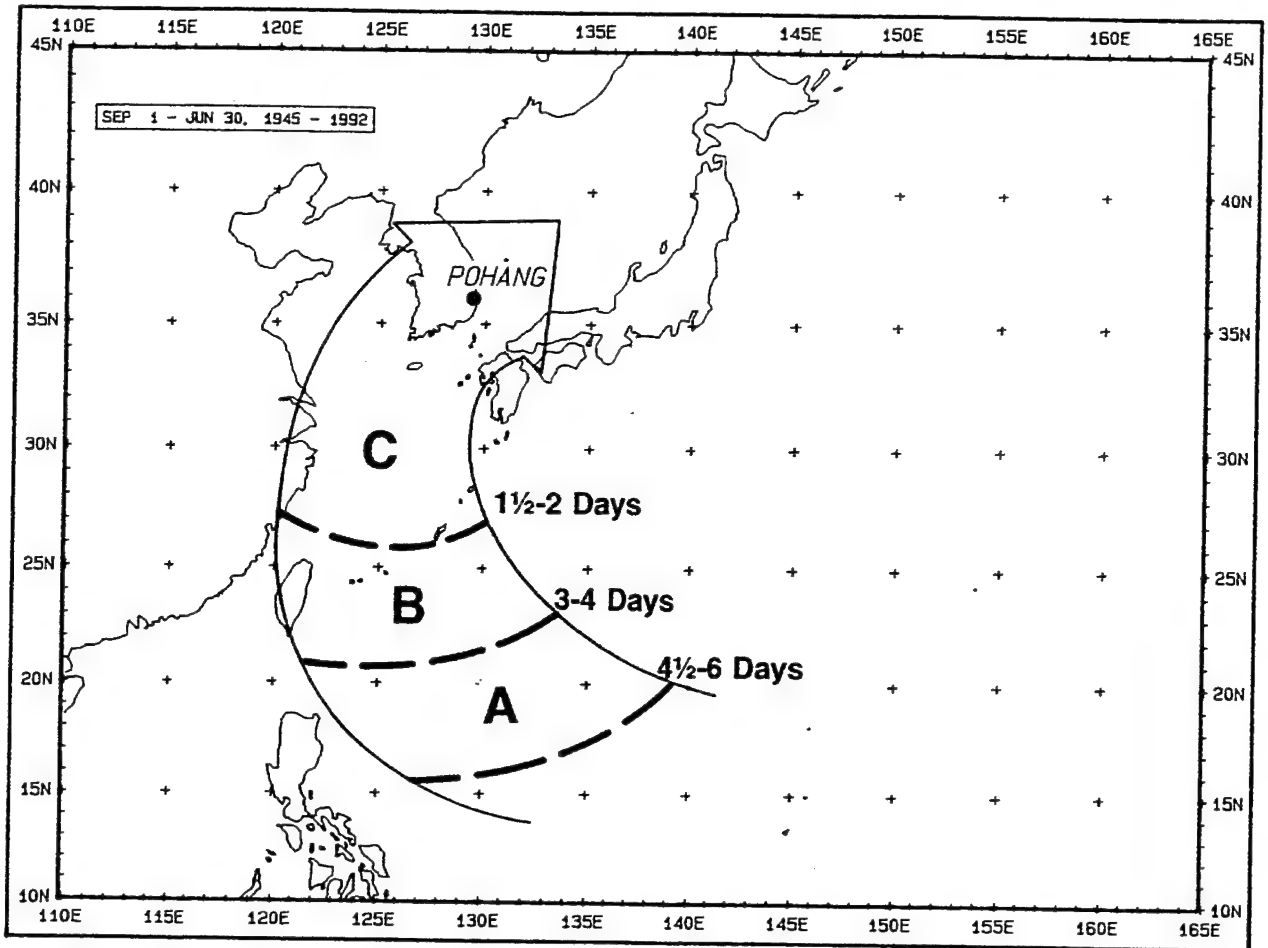

Figure VII-49. Tropical cyclone threat axis for Pohang for the period September through June.

The following time/action sequence, to be used in conjunction with Figures VII-48 and VII-49, has been prepared to aid the commander in planning ship operations.

I. An existing tropical cyclone moves into or development takes place in Area A with forecast movement toward Korea:

a. Review material condition of ship. A sortie may be necessary in 48 hours or less.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 48 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

II. Tropical cyclone enters area B with forecast movement toward Pohang (recall that tropical cyclones tend to accelerate rapidly after they have recurved):

a. Operational plans should be made in the event a sortie is required. A sortie may be necessary within 24 hours.

b. Reconsider any maintenance that would render the ship incapable of getting underway within 24 hours.

c. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning.

III. Tropical cyclone enters area C with forecast movement toward Pohang.

a. Execute plans made in previous steps.

b. Plot NPMOCW/JTWC Guam warnings when received and construct the danger area. Reconstruct the danger area for each new warning until the storm threat has passed.

5.6.2 Remaining in Port

Remaining in port at Pohang during the passage of a tropical cyclone is not recommended. Ships should sortie from the port at the first indication that a tropical cyclone will at some time enter the 180 nmi threat radius of the port.

5.6.3 Evasion

Evasion from Pohang Harbor, including the man-made basin and anchorage, is the recommended course of action for all

U. S. Navy ships when the port is threatened by a tropical cyclone. Reasons for the evasion recommendation include:

(1) Lack of protection from wind in the man-made basin, and possibility that waves may enter the basin.

(2) Exposure of the anchorage to wind and waves.

Sortie options include moving to anchor in Chinhae Bay, or evading into the Sea of Japan or Yellow Sea. Whichever option is chosen, the sortie must be initiated sufficiently early to avoid the effects of the storm.

Chinhae Bay is located southwest of the port of Chinhae (35°08'N 128°38'E) and offers good protection for ships in all but the strongest tropical cyclone threat situations. Chinhae is located on the south coast of Korea approximately 100 nmi transit distance from Pohang so, at an SOA of 20 kt, it would take about 5 hours to reach Chinhae Bay. The port of Chinhae is discussed in Section VII-4 of this manual, and the location of Chinhae Bay is identified on Figure VII-27.

If evasion to the Sea of Japan is selected, the commander must be aware that the ship may be placed in the stronger, and therefore more dangerous, semicircle (the right side of the storm with respect to the storm's direction of movement). The following factors should also be considered:

(1) Lead time. Since tropical cyclones tend to increase their speed of movement after recurvature, planners must provide for an early departure in order to clear the area before the storm's circulation arrives. A storm movement in excess of 30 kt is not uncommon while the storm is still in the vicinity of the Tsushima (Korea) Strait, and may accelerate further when the storm

reaches the Sea of Japan. The potentially rapid speed of the tropical cyclone may allow it to overtake evading ships unless the sortie is carefully planned and initiated early in the decision process.

(2) Other potential havens. If the evading unit(s) do not wish to sortie across the Sea of Japan, or if it appears that the storm may overtake the evading unit(s), commanders may wish to consider using the port of Maizuru, Japan as a typhoon haven. The Port of Maizuru (35°29'N 135°23'E) is evaluated in Section V.9 of this manual.

If evasion around the southern coast of Korea to the Yellow Sea is selected, commanders should consider the following:

(1) Lead time. Since tropical cyclones tend to increase their speed of movement after recurvature, planners must provide for an early departure in order to clear the area before the storm's circulation arrives. It is approximately 300 nmi from the port of Pohang to the eastern side of the Yellow Sea, so at a steaming speed of 20 kt, it will take about 15 hours to accomplish the transit.

(2) Storm movement. The evading unit(s) must move closer to the storm's circulation during the transit south along the east coast of Korea. Consequently, the storm may be as much as 300 nmi (or more if the storm speed exceeds 20 kt or if the evading unit(s) SOA is less than 20 kt) closer to Korea by the time the Yellow Sea is reached.

Whichever option is chosen, ship captains should remember that tropical cyclones are historically unpredictable, especially in the recurvature phase. The 48-hour forecast position error may exceed 200 nmi. Consequently, the storm may be closer to or farther from Pohang than the forecast indicates, or be right or left of its forecast track.

Port Visit Information

September 1993: NRL Meteorologist CDR R. G. Handlers, USN and SAIC Meteorologist Mr. R. D. Gilmore met with LCDR T. Knowles, USN, QMC M. T. Miller, USN and Mr. Hae-il Cho, of Port Operations, Commander Fleet Activities, Chinhae; Mr. Eui Hong Yu, Director, Pohang District Maritime and Port Authority; and Mr. Kwang Ho Bae and Mr. Tae Jun Kim of the Pohang District Maritime and Port Authority to obtain much of the information contained in this port evaluation.

REFERENCES

FICPAC, 1993: Port Directory for Pohang, South Korea, Change 22. Published by Fleet Intelligence Center, Pacific, Pearl Harbor, HI.

Harris, D. L., 1963: Characteristics of the Hurricane Storm Surge. U. S. Weather Bureau, Technical Data Report No. 48, U. S. Department of Commerce, Washington, DC.

Nestor, W. J. R., 1977: The Environment of South Korea and Adjacent Sea Areas. NAVENVPREDRSCHFAC Technical Report No. 77-03. Published by Naval Research Laboratory (formerly Naval Environmental Prediction Research Facility), Monterey, CA 93943.

Pore, N. A. and C. S. Barrientos, 1976: Storm Surge. Marine EcoSystems Analysis (MESA) Program, MESA New York Bight Project, New York Sea Grant Institute, Albany, NY